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PRELIMINARY NOTES ON DAMAGE TO APPLES BY CAPSID BUGS.

By J. C. F. FRYER, M.A.,

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(With Plates IX and X.)

THAT plant bugs of the family Capsidae can be responsible for a serious form of injury to apples has been recognised in this country for several years. Cases have been recorded by Theobald [1] and by Collinge [2] while complaints have been received from time to time by the Board of Agriculture from fruit growers in various parts of the country. On the continent brief references can be found to the Capsidae, notably to the genus *Lygus*, in most works on economic zoology, but the precise form of injury here dealt with does not seem to have been generally recognised. In America members of the Capsidae are well known as pests to both apples and pears and, though with the exception of *Lygus pratensis* Fab. the species there are not those found in Europe, yet the type of injury produced seems to be much the same. In this connection attention may be drawn to the papers of Taylor [3] on *Lygus pratensis*, of Crosby [4] on *Heterocordylus*[1] *malinus* Reut. and *Lygidea mendax* Reut., and of Caesar [6] on the two latter species and on *Neurocolpus nubilus* Say. and *Paracalocoris colon* Say. where full accounts may be found both of the insects and the injuries they produce. It will suffice to point out here that at least one author, Caesar, has found some difficulty in showing which of the various species found on apples are actually responsible for the damage and that while Crosby in the U.S.A. lays most of the blame on *H. malinus* and *L. mendax*, Caesar in Canada attributes the injury primarily to *N. nubilus* and *P. colon*, treating the two previous species as of secondary importance. The difficulty in the identification of the actual cause of the damage has also been felt

[1] An allied species, *H. flavipes* Matsuma damages apples in Japan. Nitobe [5].

in England and this paper is intended partly to throw more light on this question—though it has for its primary object the attraction of more attention to the subject at large, since the actual loss which may result from the attacks of Capsids is very serious.

As in the case of most plant bugs (*L. pratensis* is sometimes an exception) the primary cause of the damage is a puncture made by the bug in feeding. The juices of the plant are drawn up through this wound and either on account of the direct loss of sap or possibly from the injection of some irritant poison the surrounding tissues are more or less injured, the extent of the injury varying with the condition and portion of the plant attacked. In the case of apples the injury takes place very early in the season, probably before the blossom opens, when the tissues of the developing fruit and foliage are soft and in a state of rapid growth. The bugs responsible have then but recently been hatched and are very small; they appear to feed equally on the young fruit, foliage and young shoots, all of which suffer to some extent, though the injury to the fruit is the serious feature. The puncture of the bug appears to cause a definite check to the surrounding tissues so that, as the fruit grows, some parts develop more rapidly than others and a badly shaped, distorted apple is formed. When the check is very severe all growth ceases near the wound and as the remainder of the fruit swells rapidly a crack appears and may extend the whole length of the apple. A further feature often present is a more or less extensive discolouration or "russetting," which seems to arise from the abnormal development of the damaged cuticle. Finally the surface of the fruit may show a number of small pimples which so far as is known at present are the result of the unhealthy healing of the punctures. In the young fruit the actual puncture is readily seen but later it becomes obliterated and there is not as a rule any discolouration in the flesh of the apple as described by Caesar in the Canadian attack. It will be noticed that some of these forms of injury may also appear from other causes and are not infrequently attributed to some climatic action, as for instance to cold winds or excessive moisture. Although it seems probable that Capsid injury is more common than is generally supposed, at the same time it is obvious that all checks to the developing tissues of the fruit would be likely to produce very similar results so far as the mature fruit is concerned.

The injury to the foliage is perhaps more definitely diagnostic of an insect attack. As in the case of the fruit the puncture affects the surrounding tissues so that an attacked leaf shows numerous brown

spots, usually near its base, where the proboscis of the bug has penetrated. The leaf is frequently undersized and badly shaped and when it becomes old the small patches of dead tissue round each puncture may fall away, producing a very ragged condition. Distortion of the young shoots has been noticed by Theobald and this feature of the attack was also observed in 1913. All damage to both fruit and foliage is completed early in the season and though the bugs continue to puncture the foliage little harm seems to ensue.

The sum of the damage detailed above is very considerable. The injured fruit is almost unsaleable and cases were visited where 30 %–50 % of the crop was stated to have been affected, and in this estimate no account was taken of fruit so damaged that it fell off before reaching maturity. A further serious feature of the attack is that it seems to preserve a high intensity for several years consecutively in the same orchard and is not like the many diseases which vary within wide limits year by year.

In distribution, this Capsid attack is very local and is not known to be widespread in any district; at present it is known to occur sporadically in Kent, Suffolk, Nottingham, Worcester and Hereford.

As regards the different varieties of apple it is not possible yet to say that any kind is either immune or specially susceptible, since facts obtained from one affected orchard were negatived by observations in the next. It certainly appeared that the trees in the affected orchards were not in a good state of health. Mr G. P. Berry, of the Board of Agriculture, examined all the affected orchards and he was able to confirm this view. A number of soil analyses were therefore made in the hope of obtaining further light in this direction, but the work was fruitless for the soils in most cases showed no marked deficiencies in composition or other disability adequate to explain the apparent low state of health. It is still felt however that this side of the problem offers material for investigation since a tree not in a flourishing condition would naturally be less able to withstand the Capsid punctures than a healthy tree.

Turning next to the problem of the species of Capsid responsible for the damage, a few notes may be given on a somewhat cursory survey of four of the affected orchards, all of which are of large size and have suffered greatly from the disease for several seasons consecutively. An ordinary Bignell beating tray was used to obtain specimens and attention was paid to insects which were present in large numbers or belonged to a species to which the damage had previously been attributed. These

species are (1) *Lygus pratensis* Fab., (2) *Psallus ambiguus* Fall., (3) *Ȧtractotomus mali* Mey., (4) *Plesiocoris rugicollis* Fall., (5) *Orthotylus marginalis* Reut. The first of these, *L. pratensis*, may be dismissed at once from the enquiry since only one or two specimens in all were found in the affected orchards. Its mode of injury too, as described by Collinge and Taylor, differs from that actually observed, and consists in a dimpling of the fruit. *L. pratensis* is a species which hibernates as an adult, and lays eggs in the early spring ; occasionally these eggs are laid under the cuticle of the young apple, and as the fruit grows a dimple is formed, which persists until the fruit is mature. In the case of this species, therefore, the injury is not always the result of the punctures made by the bug in feeding.

As regards the other species just mentioned, their distribution in the affected orchards may be seen from the accompanying table. In the same table a few selected unattacked orchards are given to show which species may be present in an orchard without producing injury.

	Psallus ambiguus	*Atractotomus mali*	*Orthotylus marginalis*	*Plesiocoris rugicollis*
1. Suffolk affected	X	X	O	X
2. Worcester affected	X	O	X	X
3. Worcester affected	X	X	X	X
4. Worcester unaffected ..	X	O	X	O
5. Nottingham affected	X	O	X	O
6. Hertford unaffected	X	X	O	O
7. Cambridge unaffected ..	X	O	O	O

Note. In No. 3 *O. marginalis* was scarce. In No. 4 two specimens only of *O. marginalis* were obtained. In the other cases the " X " implies that the species was exceedingly abundant, the " O " that it was absent

Taking these species singly it will be seen that *P. ambiguus* was found abundantly in all orchards and can hardly be the cause of the damage. It is a small brown or red species which is usually very common on apples everywhere.

The second species, *A. mali*, was considered by Theobald to be responsible for injury in Kent ; in the present case it was absent from two affected orchards, present in the other two, but also present and in large numbers in an unaffected orchard. It is not therefore considered here to be a markedly injurious species. In colour and shape it somewhat resembles *P. ambiguus*, but may at once be known by its small size and thickened antennae. The third and fourth species, *P. rugicollis* and *O. marginalis*, may be considered together. Both species were present in two of the affected orchards and in each of the other cases of attack

one or other was present. Further they were absent from the unaffected orchards with the exception of one in Worcester where *O. marginalis* was recorded as present from two specimens only. It therefore appears that one or both of these species are responsible for the injury, and this opinion is strengthened by an experiment carried out by the proprietor of an affected orchard in Worcester. This experiment consisted in excluding the larvae of these species from a number of trusses and also in enclosing them with others. The trusses from which the bugs were excluded developed sound fruit, while the apples enclosed with them sustained typical capsid damage. It is hoped to repeat this experiment with *P. rugicollis* and *O. marginalis* separately, in order to confirm suspicion as to their both being responsible for damage—in the meantime they must be left to share the responsibility between them. In colour *O. marginalis* and *P. rugicollis* differ from *Psallus* and *Atractotomus* in being green or yellowish-green; they closely resemble each other superficially and may easily be confused in the field. The presence of a rounded ridge or collar towards the anterior margin of the pronotum will always distinguish *P. rugicollis* from an *Orthotylus*, while in addition the former species is broader and stouter than the latter, characters which give it a somewhat different appearance. Both species are on Theobald's list of suspects, in his articles on the subject, in the *Journal of Wye College*, which also contains a quotation from Schoyen to the effect that these species are harmful to apple and currant in Sweden. Of neither species is the life history known. Mr E. A. Butler, who was consulted on the subject, kindly gave the information that both species were usually found on willow or alder, though Reuter, who described *O. marginalis*, mentions apple as one of its food plants. Further, in Mr Butler's experiences, these species appear rather late in the season, larvae being found in June and July, and adults at the end of the latter month and in August. In the cases now under consideration, *P. rugicollis* was adult in Suffolk on the 13th June and one or two pairings were then observed. *O. marginalis* was adult in Worcester on the 24th June, but many specimens were still immature, and it appears to be a later insect than *P. rugicollis*. Both species, however, must have hatched towards the end of April and there is thus a considerable discrepancy between the observations here recorded and those of Mr Butler. The possibility of two broods naturally suggested itself but this is considered as most unlikely by authorities on the Hemiptera. Examples sleeved on apple trees in June failed to produce a second brood, and up to the present no eggs have been discovered, and their exact situation is unknown. It is assumed temporarily that apple has

somewhat recently been adopted as a food plant, and that this change has brought about an alteration in the time of appearance of the insects. However this may be, it is evidently useless to speculate on the biology of these species without further observations and this paper may be concluded by a reference to the very meagre notes on "treatment" which have been gathered.

Since the damage is done soon after the insects leave the egg it is evident that any treatment by means of spraying must be carried out at exactly the right time, and the spray must of course be one which kills by contact. Crosby, in America, found that paraffin emulsion, whale-oil soap and lime sulphur were of little service. Preparations of nicotine and soft soap gave fairly good results and were recommended with the caution added that the trees must be very thoroughly drenched with the wash. The spray was to be applied both before the blossom opens and after it falls. In England, a wash of this nature has been found partly successful, but in one case no benefit whatever resulted, the reason given being that the bugs hatch out over a long period. In this case, both species were present and if *O. marginalis* is later in appearing than *P. rugicollis*, it is probable that this explanation is correct. The possibility of a winter wash against the eggs is hardly worth considering, for apart from the failure of winter washes against insect eggs in general, it will probably be found that the eggs of these bugs are deeply imbedded in the bark of the twigs, quite out of the reach of all sprays. The problem of dealing with these bugs in some ways resembles that of the apple sucker (*Psylla mali*) and is likely to be as difficult. At present, therefore, the only treatment which can be suggested is a spray of soft soap and nicotine, or possibly soft soap and quassia, but success will depend on a nice estimation of the exact time to apply the wash, and the thoroughness with which the application is made. Cases such as this bring out clearly the need for further experiments in insecticides, especially in "contact" insecticides, with the object of finding an efficient substitute for the expensive nicotine and if possible of increasing the number of reagents from which to choose.

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3. Taylor. *Journal of Economic Entomology,* vol. i. p. 371.
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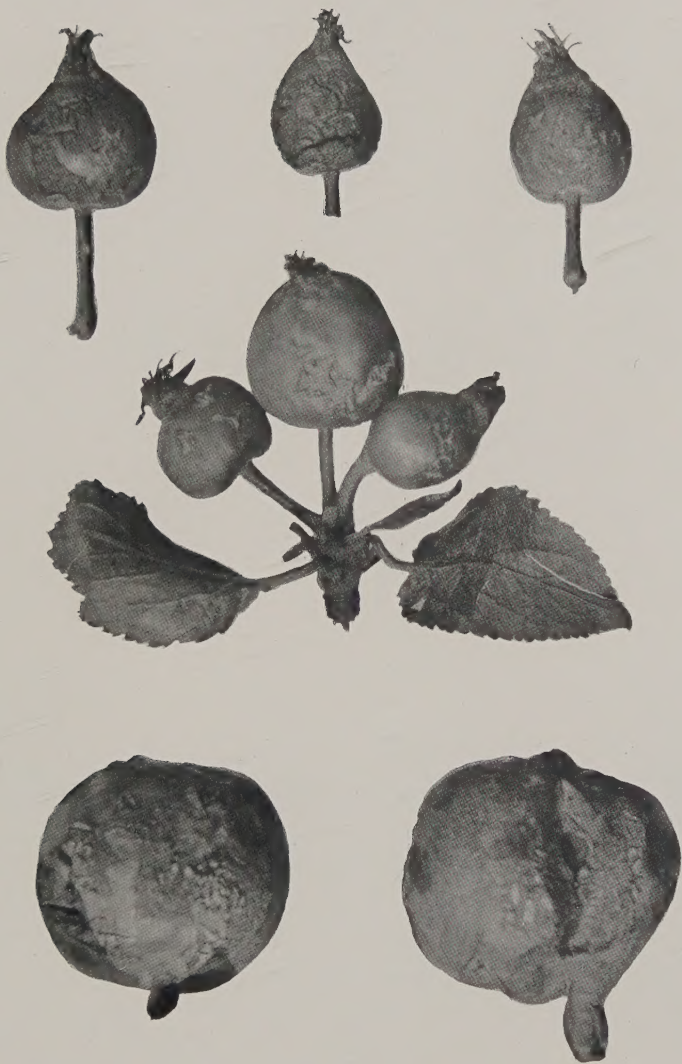

Apples to show distortion and cracking due to punctures by Capsid bugs. Natural size.

A.

B.

C.

D.

E.

Fig. *A. Plesiocoris rugicollis.* Fig. *B. Orthotylus marginalis.* Fig. *C. Lygus pratensis.* Fig. *D. Atractotomus mali.* Fig. *E. Psallus ambiguus.* Each specimen × 3.

THE INTERNATIONAL PHYTOPATHOLOGICAL CONFERENCE, 1914.

By A. G. L. ROGERS

Horticulture Branch, Board of Agriculture and Fisheries.

The International Phytopathological Conference which was opened at Rome on the 24th February last and was brought to a conclusion on the 4th March, is the outcome of a long agitation. According to the *Report* prepared by M. Louis Dop, and circulated to the Delegates before the Conference began, the first proposal for international action was made by Professor Eriksson as far back as 1880. Similar proposals were made from time to time at different International Congresses, but with little result, except that at the Seventh Congress of Agriculture, held in 1903, a special Committee on plant diseases was formed, and the *Zeitschrift für Pflanzenkrankheiten* started as their official organ, under the editorship of Professor Sorauer. The publication is, however, international only in the sense that papers from authors of any nationality are accepted, and the Governments of the chief states are in no way involved. The first real step towards international action was taken in 1905, when the Institute of Agriculture was founded at Rome, and the subject of plant diseases definitely included among the subjects with which it was competent to deal. Further progress was made when the French Government were invited by a resolution passed at the International Congress for Comparative Pathology at Paris in 1912, to take the initiative by calling an International Phytopathological Conference at Rome. Invitations were sent out for a meeting in 1913, but the notice given was inadequate, and the meeting was postponed till 1914. The Conference which has just been concluded is therefore very largely due to the action of the French Government, and certainly the initiative was taken by the French delegates throughout the proceedings. M. Develle, a former Minister of Agriculture, was elected

President of the Conference at the opening meeting, and M. Louis Dop, the permanent representative of France at the International Agricultural Institute, took a prominent part in the direction of business. The chief credit, however, belongs to the French technical delegates, headed by M. Mangin, whose persistence and readiness in debate, coupled with his fertility in devising expedients for overcoming difficulties, carried all before him. The prominent position occupied by the French delegates in the Council chamber, and the fact that the discussion was carried on in their native language, and in accordance with the usage of their Parliamentary procedure, no doubt gave them a great advantage over other delegates, an advantage, however, which they never abused.

As many as 30 States were represented, and the Conference was informed that certain other countries accepted the principle of an International Convention in advance. The only notable sovereign state unrepresented was the United States of America but no delegates were sent by South Africa, Australia, New Zealand, or any of the smaller colonies. The instructions given to the three English delegates were simple. We were not authorised of course to commit our country to any binding agreement, but this was the less important because it was made very clear at the beginning of the debate that no delegate had such powers, and that no proposal would be made which would not be submitted for the approval of our Government through the Foreign Office, for subsequent ratification by plenipotentiaries appointed for the purpose. We were authorised, however, to accept on behalf of the Board, the principle of a Convention, and to press for three cardinal points: (1) that plants coming from a nursery that had been inspected and found free from important diseases, should be allowed entry if accompanied by an official certificate of health, and that it should not be necessary that each consignment should be specially examined; (2) that the certificate should specify the diseases for which the nursery had been examined, and (3) that consignments accompanied by the official certificates should not be detained at the frontier for re-examination by the officials of the country of destination. It was thought that if we could secure these points, the hindrances to trade, which had in recent years grown up in so many countries, would be removed, and that a wide field for the development of English commerce in plants would be opened. As events turned out, we had singularly little difficulty in getting these principles conceded. The first two points were pressed for by the delegates of other countries, and were agreed to without opposition, and though the delegates present

would not agree to surrender entirely the right of examination on arrival, the first delegate of England pressed our claim so skilfully that an assurance was understood to be given that the right would rarely be exercised if it was found that the inspection in this country was thorough and the consignments were found to be healthy. It is most improbable that any further concession would have been gained by pressing the claim any further.

The Convention which was ultimately drafted, and signed by all the delegates present, may be summarised as follows. Adhering States pledge themselves to form at once, if they have not already done so, an official service of inspection of all nurseries, glasshouses and other establishments offering plants for sale. They shall be prepared to issue phytopathological certificates, control the movement of plants, and the methods of packing and means of transit of the same, organise a service for the suppression of dangerous diseases, and otherwise fulfil the usual functions associated with a phytopathological department of State. No State can adhere unless this is done at once. But it must also undertake to create within two years, if it has not already done so, one or more institutes for enquiry and research, obviously so that the Administrative Department may be supplied with the best scientific and technical advice possible. The State must pledge itself to issue certificates with all consignments of plants sent abroad and to receive consignments accompanied by such certificates from other adhering States, and better terms must not be given to States that do not adhere than to those that do, while States with common borders may make special arrangements with each other with regard to the movement of plants. All this is elemental, and no Convention would be possible without some such agreement. But the really important point of the Convention consists in the way in which this system is to be applied. It was agreed with very little discussion that the Convention should not apply to certain kinds of plants. Grain, seeds, potatoes, onions and general farm produce—articles de grande culture—to use the exact words, are excluded. Presumably, States may make their own regulations as regards such produce, but it was generally felt, I think, that it would be inadvisable in most cases to make any regulations at all. Most delegates felt that the service at present in force in their own country would be incapable of such a system of inspection, as would make the certificates of any real value. Vines also were excluded as being dealt with under the Berne Convention, to which every State that joined the Rome Convention would be expected to adhere. On the other

hand, a vigorous stand was made for the inclusion of cut flowers and bulbs of the flowering kind, a matter which is likely to give some countries a good deal of trouble. Finally, an important discussion took place on the diseases for which inspection is to take place. A single certificate of health was felt to be insufficient; a list of diseases prepared by the Conference too fruitful a subject for dispute; and after a short debate it was unanimously decided to leave each country to prepare its own list of the diseases against which it wished to be protected. The preparation of this list will be a matter of extreme difficulty, and may have an important bearing on the nature of phytopathological research. But the really important article is that which lays down the rules on which the list is to be prepared. This article was drafted by a special Sub-Committee though modifications were introduced when the report was presented to the Committee and, as far as my recollection serves, at the final sitting of the Conference. It prescribes that the list is to be as restricted as possible, that no pests are to be included whose host plant is not to be found in the country of destination, and that the common pests whose distribution have been widespread in almost every country for many years are to be excluded. This in itself would be sufficient to keep the list from being unduly long, since few people could be found who would object to the inclusion of such pests as could properly fall within the category left open. But in order to emphasise the limitations two further definitions were proposed. On the motion of one of the Danish delegates it was decided that the pests must be capable of being easily conveyed by living plants or parts of such plants, and on the suggestion of one of the English delegates it was agreed that the pests must be epidemic in character, and destructive or at least injurious to the plant. It was explained that destructive meant destructive to the life of the plant, and that injurious meant destructive to the commercial value of the crop, or to that part of the plant for the economic use of which the plant itself is cultivated. This article would prevent such a pest as *Nectria ditissima* being included, though it appeared on several of the provisional lists presented by delegates present at the Conference, since it is not only of old standing and general distribution but it cannot be said to be destructive to the tree or to the crop it bears. There are plenty of apple trees in this and other countries, which have been cankered for many years and yet continue to bear a serviceable crop of fruit.

The proposed Convention is not a very drastic affair, and it is quite as likely to be attacked on the ground that it does not go far enough

as on the score that it goes too far. But for many reasons, I think it is a great step in the right direction. It establishes the principle of international action in the first place, and of international unity in the second. It implies direct administrative effort to control dangerous plant diseases, and it checks excessive and unreasoning restrictions. It is based on the principle of mutual trust, and the procedure contemplated is the productive method of the eradication of disease at home in place of the present wasteful system of inspection of foreign consignments. It will, I hope, promote trade and not hinder it. It will benefit both the nurseryman and the consumer. These considerations cannot be overlooked by administrators and pure economists. But on this occasion it is natural that other questions should be asked. Scientists may well demand whether it will promote the cause of learning, and encourage research or if it will by establishing administrative rules and procedure, which will tend to become stereotyped and inelastic, hinder the application of new scientific discoveries and become a bar to progress. It is difficult to forecast the future. We all know how the wisest laws, if maintained after the need for them has ceased, prove instruments of reaction, and it is impossible to say that no flaw will ever be found in this Convention, or that it will never be open to criticism. There are some people who object to State action in such matters on principle, and others who do not believe that regulations can check the spread of disease. Such persons will no doubt view the whole idea of a Convention with disapproval. But to those who are prepared to accept the principle that epidemic diseases can be checked by State action, and probably by State action alone, I would point out that this is the first time that any Convention, so far as I am aware, has made it an essential part of the obligations of each adhering State, that scientific research must be associated with administrative action : that this Convention gives economic biology and phytopathology a status they never had before, and both directly and indirectly offers a new field for scientific research.

THE HOST PLANTS AND HABITS OF *APHIS RUMICIS* LINN., WITH SOME OBSERVATIONS ON THE MIGRATION OF, AND INFESTATION OF, PLANTS BY APHIDES[1].

By J. DAVIDSON, M.Sc., F.E.S.

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Introduction.

The following experiments are the first of a series of experiments and observations on the habits and life-history of the Aphididae, which the author hopes to carry out, with the hope that our knowledge of the migratory habits of these insects, and the infestation of plants by them, may be increased.

The results obtained this season do not afford sufficient data upon which to base any definite explanations of these problems. Many of the observations, however, have suggested certain lines of enquiry.

In the latter part of this paper, the author has briefly discussed some of the factors which may underly the questions of the migration of Aphides and the infestation of plants by them.

Some tentative suggestions as to the nature of these factors have been made, with the hope that deeper enquiries into the habits of this important family of insects may be stimulated. These suggestions are based upon observations made in connection with these experiments.

In September, 1912 (*op. cit.* below), Theobald published an interesting paper dealing with the habits and life-history of *Aphis rumicis*, in which this author describes a double life-cycle for this species. In one cycle ova are produced by the sexuparae, in late Autumn, on Rumex plants. These ova hatch out in Spring, and subsequently winged migrants are produced on the Rumex plants. These migrants go, about June, to

[1] The species of Aphis used is the black aphis found in spring on *Euonymus europaeus* (*Aphis euonymi*). It is now considered as one of the many synonyms of *Aphis rumicis*, *vide* Theobald, F. V. (1912), *Journ. Bd. of Agric.* vol. xix, No. 6, Sept. 1912, pp. 466–476.

Broad Beans, which plants they heavily infest throughout the Summer. In Autumn the winged migrants from the Broad Beans return to Rumex, sexuparae being produced in late Autumn, and subsequently ova being laid on the Rumex plants.

In the second life-cycle, ova are produced by the sexuparae on Euonymus in late Autumn or Winter, which hatch out in Spring. The winged migrants subsequently produced migrate to Poppies in June, which plants they heavily invest as *Aphis papaveris*. In some years, when the number of Aphids produced is abnormal, some of the migrants go from the Poppies to Mangolds and many plants of the Chenopodiaceae family. In Autumn the winged migrants return to Euonymus where sexuparae are produced and ova laid.

The aphids taken from these different plants showed no structural differences, although they differed slightly in size or colour on the different host plants.

It seemed to the present author that, if these two parallel life-histories for *Aphis rumicis* were stable, the question of the influence of the host plants on aphids is an important factor. The two life-cycles seemed to show that the preceding host plant upon which a generation of aphids is produced, has a determining influence on the species of plant subsequently selected by the winged migrants.

Theobald found that winged viviparous females taken from Euonymus lived on Broad Beans, and gave rise to the " bean black fly," but from field observations he was unable to trace whether the winged migrants from Euonymus went to Broad Beans.

This seemed to the present author to be a very important question in connection with the two life-cycles described for *Aphis rumicis*. It intimated that the two parallel life-cycles might be merged into one by crossing from Euonymus to Broad Beans, and from Rumex to Poppies. If the two life-cycles proved to be absolutely constant and separate, a very important feature would be established, namely the establishment of two biological species (*A. euonymi* and *A. rumicis*), both resembling each other in structure but differing physiologically in habits.

As the results obtained in these experiments will show, *Aphis euonymi* will heavily infest Broad Beans, and *Aphis euonymi* reared on Rumex will heavily infest both Broad Beans and Poppies. Thus the two life-cycles may be merged into one. The life-history, however, has not been completed, as owing to leaving England in September, I have been unable to trace the history of the sexuparae. However, the plants are still under observation, and the ova will be looked for in due course.

In concluding this general introduction, it may be added that the experiments, series *B* and *C*, have been carried out as far as possible under natural conditions.

The plants in the pots in series *A*, did not in some cases flourish as well as might have been expected, owing to the dry summer.

Experiments. Series A, B and C.

The aphis species used in series *A*, *B* and *C*, is the Black Euonymus Aphis (*A. euonymi*). All the aphids used in the first two series were reared from a small colony found in January (27. 1. 1913) on a small Euonymus bush in a garden near Richmond. In this way one was quite certain that the same species of Aphis was being used throughout, and further one knew exactly the history of the different generations produced as the various plants were infected.

The original colony on Euonymus was taken to the College greenhouse, and the plant covered with a muslin bag. When winged forms were produced, a clean Euonymus plant was infected.

The experiments have been made in three series, *A*, *B* and *C*, and have been carried out at Acton Lodge, Brentford, Middlesex, the experiment orchard for the Department of Economic Entomology, Royal College of Science, London. My sincere thanks are due to Professor Maxwell-Lefroy for the kind and generous way in which he has given me every facility for carrying on the work.

The notes and observations given under the various dates will show the results obtained.

Experiments. Series A.

The various plants indicated below, were infected with winged viviparous females in every case, except in the case of Rumex, No. 2, the aphides being transferred by means of a fine camel hair brush. The plants were raised in pots from seed and kept covered with muslin bags so that they were quite proof against external infection. During rainy weather the plants were kept in a partly closed frame, but otherwise they were kept in the open as much as possible. Observations were made from time to time and notes made as given below.

It will be seen in experiments, series *A*, that the chief food plants of *A. rumicis* have been infected from different hosts; thus, plants Nos. 1, 2, and 3, were infected with aphids bred on Euomymus, plant *B*. Similarly plants Nos. 4, 5 and 7 were infected with aphids bred on plant No. 1, and so on.

NOTES AND OBSERVATIONS ON PLANTS IN SERIES A.

Plant No. A. Euonymus europaeus.

Found infected with a small colony of *A. rumicis*, at Richmond, 27. 1. 13 and transferred to College greenhouse. The colony developed, and about the middle of February, many winged viviparous females were produced. These swarmed over the plant which became heavily infested. At the end of February, the aphids swarmed over the plant in vast numbers. Many of them died off. The winged forms crowded round the muslin bag, as though wanting to escape, and dissatisfied with the plant. Many of the young shoots of the plant were killed, and the aphids all died. The plant was kept covered till May 23rd, on which date there were no living aphids present. It was then reinfected with *Aphis euonymi*, from some Euonymus trees in Acton Lodge garden, and they produced several small colonies on the young growing shoots of this plant.

It should be noted that owing to a hard frost occurring early in February, the greenhouse was heated at night so as to make sure that the aphids would not die. This doubtless hastened the production of winged forms.

Plant No. B. Euonymus europaeus.

This plant was infected from No. *A*, about the third week in February, with three winged viviparous females. They produced colonies of apterous females. Winged viviparous females (2nd generation) appeared on this plant on April 27th. By the 20th May, the aphids were very numerous on this plant, and both the apterous and viviparous females were actively running over the plant, on the stakes supporting the muslin bag covering it, and crowding over the muslin, as though wanting to escape. By the end of the first week in June, many of the aphids were dying off. The aphids were much smaller than the members of the original colony, this no doubt produced by the fact that they were not feeding on the plant. Some specimens of the winged forms, which I preserved at this stage, show that the abdomen is small and shrunken in appearance. The apterous forms were also small, and present in extraordinary numbers. Contrary to their usual sluggish habits, they were actively running over the stakes supporting the muslin cover.

On May 5th, I put one apterous viviparous female from *B* on a clean branch of a small Euonymus bush, and on another branch I put a winged viviparous female from *B*. These both produced lice in 3 days, and although the numbers produced, even after a month, were very few, yet the individuals looked fat and healthy.

Plant No. 1. Rumex sanguineus.

5. 5. 13. Infected from Euonymus *B*, with 4 w. viviparous ♀'s.

7. 5. 13. A few aphids produced.

22. 5. 13. Many colonies present; collected round the apex of the young shoots, also several colonies along the mid-rib of the leaves. Some of the apterous forms are a smooth, shiny, jet black, colour, but many of them are covered with a mealy bloom.

26. 5. 13. A few winged forms produced.

29. 5. 13. The aphis infests the stem in vast numbers, almost along the whole of its length, also beneath the leaves along the mid-ribs. They are big, healthy individuals, the winged forms being much larger than those present on Euonymus *B*. Most of the winged forms are actively walking on the muslin cover as though wanting to escape.

4. 6. 13. Enormous numbers of winged forms are now present, crowding round the top of the muslin cover, and not on the plant at all. It is noticeable that during the progress of the infestation, the colonies of apterous forms first collected at the apex of the young growing stem, and gradually extended towards the base, until the whole stem was covered. Many also along the mid-rib, and main veins of the leaves.

24. 6. 13. Plant dead, all the aphids dead.

Plant No. 2. *Rumex sanguineus.*

5. 5. 13. Infected from Euonymus *B* with four apterous viviparous females.

7. 5. 13. Several aphids produced.

22. 5. 13. Several colonies present on this plant, also nymphs of winged forms produced. Colonies present on mid-rib beneath the leaves.

26. 5. 13. A few winged forms produced.

29. 5. 13. Now fairly heavily infested, but numbers not so great as in case of No. 1; there are fewer winged forms present.

4. 6. 13. Aphids not nearly so numerous as in No. 1; chiefly collected at top of the stem, but one colony forming half-way down. A few winged forms present, walking on the muslin cover. Several colonies beneath the leaves, on the mid-rib and veins.

16. 6. 13. Plant fairly heavily infested; numbers of w. v. ♀'s, which are crowding round the top of the muslin cover. Infestation not so heavy as No. 1.

28. 6. 13. Plant heavily infested, vast numbers of winged forms actively crawling over the muslin cover. Many apterous forms clustered along the length of the stem, and beneath the leaves, along the mid-rib, many of these very small.

8. 7. 13. Plant dead, aphids all dead.

Plant No. 3. *Broad Beans.*

25. 5. 13. Infected from Euonymus *B* with five w. v. ♀'s.

27. 5. 13. A few aphids produced, but it would appear that the w. viviparous females from *B* are weak and are not producing happily. Reinfected with 3 w. v. ♀'s from *B*.

31. 5. 13. Only a few aphids present. Reinfected with four w. v. ♀'s from Euonymus *B*.

24. 6. 13. Many colonies produced, situated on the upper part of the stem and in axils of the leaves. A few nymphs of winged forms present. Aphids big and healthy.

28. 6. 13. Winged forms present.

8. 7. 13. Plants fairly heavily infested; many winged forms gathered at the top of the muslin cover.

14. 7. 13. Infestation heavy; many winged forms crowding in vast numbers on the top of the muslin cover.

24. 7. 13. Plant smothered with aphids; many dead; plants very sickly, leaves curled and of a dirty brownish colour.

Plant No. 4. *Broad Beans.*

27. 5. 13. Infected from Rumex No. 1, with four w. v. ♀'s.

31. 5. 13. Only a very few aphids produced, winged mothers dead. Reinfected with five w. v. ♀'s from Rumex No. 1.

Note. It is possible that the w. v. ♀'s taken from the Rumex were old, and had already laid a number of lice on that plant.

24. 6. 13. Many aphids present which are collected along the upper part of the stem. Winged viviparous females present.

28. 6. 13. Aphids numerous along upper part of stem. Many winged forms present, some settled beneath the leaves, but many collected in the top of the muslin cover as though wanting to migrate.

8. 7. 13. Heavily infested, great numbers of winged forms collected in top of muslin cover, aphids distributed all over the stem, and beneath the leaves.

24. 7. 13. Plants smothered with aphids; many winged forms dead; plants look sickly.

Plant No. 5. *Rumex sanguineus.*

31. 5. 13. Infected from Rumex No. 1, with four w. v. ♀'s.

18. 6. 13. Many colonies going on this plant, but it became diseased, and the leaves died, so the aphids were transferred to another *Rumex* plant.

Plant No. 6. *Shirley Poppies.*

4. 6. 13. Infected from Euonymus *B* with four w. v. ♀'s.

18. 6. 13. Several apterous viviparous females present, and one fairly large colony.

24. 6. 13. Several small colonies produced, but reproduction seems slow in numbers.

30. 6. 13. A few small colonies present beneath the leaves and on the stem, but numbers small.

8. 7. 13. A fairly good number of aphids present, along the mid-rib of leaves and on the stem, and flower stalks.

24. 7. 13. A good number of aphids distributed generally over the plants, which look sickly, and flowers almost over; several winged forms produced.

28. 7. 13. Many winged forms present; plants fairly heavily infested.

Plant No. 7. Shirley Poppies.

4. 6. 13. Infected from Rumex No. 1, with five w. v. ♀'s.

18. 6. 13. Several large apterous females present beneath the leaves, along the mid-ribs; very few in number.

24. 6. 13. Several colonies present, beneath leaves, and on the stem.

28. 6. 13. Plants are rather poor specimens; there are a few individuals collected along the stem, and beneath the leaves, but numbers small.

8. 7. 13. Several colonies along the stem and flower stalks, and beneath the leaves, along the mid-ribs.

12. 7. 13. A few winged viviparous ♀'s produced.

14. 7. 13. Several winged forms collected at the top of the muslin cover, as though wanting to escape. Many nymphs of winged viviparous ♀'s on the plants. Poppies in flower.

24. 7. 13. Infestation fairly heavy.

Plant No. 8. Papaver rhoea.

24. 6. 13. Infected from Rumex No. 2, with ten w. v. ♀'s.

28. 6. 13. Several aphids produced.

8. 7. 13. Several colonies going well beneath the leaves.

14. 7. 13. Plenty of colonies present along the flower petioles, and beneath the leaves; winged viviparous females produced, and several nymphs of winged forms present.

24. 7. 13. Plants are healthy; many aphids on the flower stalks, and beneath the leaves; not very many winged forms produced.

28. 7. 13. Infestation moderate.

Plant No. 9. Red Beet.

25. 6. 13. Infected from Rumex No. 2 with ten w. v. ♀'s.

8. 7. 13. The plants Nos. 9, 10, and 11 are not growing well, and have wilted considerably owing to lack of water, so that the aphids seem to have died off. Reinfected with five w. v. ♀'s from Rumex No. 5.

14. 7. 13. A few isolated individuals present.

24. 7. 13. Several large apterous viviparous females present, collected on the underside of the very young leaves.

28. 7. 13. The apterous viviparous females are collected on one small young leaf; they are large and healthy individuals, but up to the present do not appear to be increasing very much in numbers on these plants. No nymphs of winged forms or winged forms produced as yet.

Plant No. 10. Mangolds.

25. 6. 13. Infected from Rumex No. 2 with ten w. v. ♀'s.

28. 6. 13. One living winged form left, but owing to lack of water the plant has wilted, and aphids have not taken.

8. 7. 13. Only one or two individuals present. Have reinfected with five w. v. ♀'s from Rumex No. 5.

14. 7. 13. A few individuals present.

24. 7. 13. A few small colonies present on one young leaf, numbers few, four fat, healthy apterous females.

28. 7. 13. Aphids few in number; no winged females yet.

Plant No. 11. *Sugar Beet.*

24. 6. 13. Infected from Rumex No. 2 with eight w. v. ♀'s.

28. 6. 13. Plant has wilted owing to lack of water; a few young aphids present.

8. 7. 13. Reinfected this plant with five w. v. ♀'s from Rumex.

14. 7. 13. One colony going well beneath one young leaf, the individuals being healthy; a few individuals also present on the older leaves.

24. 7. 13. About 30 individuals present, collected chiefly on the underside of the leaves, along the veins.

28. 7. 13. Aphids chiefly collected on one young leaf, which is curled, but a few colonies on the older leaves. Winged forms produced, and nymphs of winged ♀'s present.

30. 7. 13. Aphids look healthy, but numbers up to the present are small.

Plant No. 12. *Onions.*

27. 6. 13. Infected from Broad Beans No. 4 with five w. v. ♀'s.

8. 7. 13. No aphids present, have left the plants and died.

Plant No. 13. *Red Beet.*

27. 6. 13. Infected from Broad Beans No. 4 with five w. v. ♀'s.

28. 6. 13. A few aphids produced.

8. 7. 13. One winged mother alive, but not many individuals produced, so reinfected with five w. v. ♀'s from Broad Beans No. 4.

14. 7. 13. A few small colonies formed on the young leaves.

24. 7. 13. Several big healthy apterous females present beneath the young leaves; a few nymphs of winged viviparous females produced.

28. 7. 13. Infection heavier than in case of No. 9, but numbers not great; winged forms produced.

Plant No. 14. *Shirley Poppies.*

27. 6. 13. Infected from Broad Beans No. 4 with eight w. v. ♀'s.

28. 6. 13. Several aphids produced.

8. 7. 13. Several colonies going well beneath leaves, on the veins; also a few individuals on the flower-stalks.

14. 7. 13. Poppies in flower; several colonies present beneath the leaves, and on the flower-stalks.

22. 7. 13. Winged viviparous females produced.

24. 7. 13. A fair number of aphids present, distributed along stems and flower-stalks; winged viviparous females present.

28. 7. 13. Many winged forms produced; infestation is moderately heavy.

Plant No. 15. *Shirley Poppies.*

27. 6. 13. Infected from Broad Beans No. 3 with five w. v. ♀'s.
8. 7. 13. A few small colonies present on the veins beneath the leaves.
14. 7. 13. Several small colonies going on the veins beneath the leaves.
24. 7. 13. Aphids seem to be chiefly beneath the leaves; several nymphs of winged viviparous females produced.
28. 7. 13. Several of the leaves curling owing to aphid colonies below; nymphs of w. viviparous females present.
30. 7. 13. Aphids only in moderate numbers.

Plant No. 16. *Shirley Poppies.*

27. 6. 13. Infected from Broad Beans No. 3 with five w. v. ♀'s.
8. 7. 13. A few colonies present on the veins beneath the leaves; Poppies just coming into flower.
14. 7. 13. Several colonies on the flower-stalks and beneath the leaves; Poppies in flower.
24. 7. 13. A moderate number of aphids present; many winged forms produced; aphids infest the stem and flower-stalks, and also collect along the veins beneath leaves; Poppies still flowering.

Plant No. 17. *Swedes.*

27. 6. 13. Infected from Broad Beans No. 3 with five w. v. ♀'s.
28. 6. 13. A few aphids produced.
8. 7. 13. One colony of three or four individuals present.
14. 7. 13. A few isolated individuals going on the leaves, but numbers very few, and no colonies forming.

Plant No. 18. *Red Beet and Sugar Beet.*

27. 6. 13. Infected from Broad Beans No. 3 with five w. v. ♀'s.
28. 6. 13. Several aphids produced.
8. 7. 13. A few colonies present beneath the leaves, on the veins, on both plants.
14. 7. 13. Numbers very small, but several healthy apterous forms on underside of the young leaves of both plants.
24. 7. 13. Nymphs of winged forms produced; several small colonies of healthy individuals present beneath young leaves.
28. 7. 13. Aphids big and healthy but not many produced; chiefly collected on the very young leaves, but a few on older leaves; nymphs of winged forms present.

Plant No. 19. *Red Beet.*

27. 7. 13. Infected from Shirley Poppies No. 6 with five w. v. ♀'s.
4. 8. 13. A moderate number of young aphids present.
10. 8. 13. Not very many individuals present as yet.

The following plants were also infested as follows.

Plant No. 20. Broad Beans.

2. 6. 13. Infected from a Euonymus tree growing in Acton Lodge garden with four w. v. ♀'s.

24. 6. 13. Many aphids now going well on the plants, along upper half of stem, and some along mid-ribs beneath leaves.

26. 6. 13. Winged females produced.

28. 6. 13. Aphids heavily infesting the plants along the stems. Many winged forms present, which are walking over the muslin bag as though wanting to escape.

8. 7. 13. Plants heavily infested; very many winged forms crowding on the muslin cover.

14. 7. 13. Bean plants almost dead; leaves curled and brown; many aphids dead.

24. 7. 13. Plants dead; all the aphids dead.

Plant No. 21. Shirley Poppies.

4. 6. 13. Infected from Euonymus tree growing in Acton Lodge garden with four w. v. ♀'s.

18. 6. 13. Several apterous forms present beneath the leaves.

28. 6. 13. Several colonies present on the stem and leaves, along the mid-ribs; aphids big and healthy.

30. 6. 13. Aphids fairly numerous, along flower-stalks and beneath the leaves.

12. 7. 13. Winged viviparous females produced.

14. 7. 13. Many winged forms produced; Poppies in flower; several colonies going well.

20. 7. 13. Infestation moderate; aphids dying off; plants sickly.

21. 7. 13. Poppies looking very sickly; aphids nearly all dead. The soil used was poor and plants did not do well.

28. 7. 13. Plants dead.

Plant No. 22. Onions.

13. 6. 13. Infected from Rumex No. 1 with eight w. v. ♀'s.

28. 6. 13. No aphids present; have died off.

Plant No. 23. Red Beet.

13. 6. 13. Infected from Rumex No. 1 with eight w. v. ♀'s. These plants were grown in the open garden, and at the time of infection were covered with a muslin cage. Although I searched carefully and found no aphids on the plants, one could not be absolutely certain that some individuals from the neighbouring infected Beans had not infected them. The plants in the pots did not, generally speaking, grow as healthily as those in the open garden, and I wanted to see the effect on these plants which were growing well. Soon after infecting them the winged forms made their way up to the top of the muslin bag, but a day or so after they seemed to settle on the plants.

28. 6. 13. A few colonies present on the underside of some of the leaves.

28. 7. 13. Several colonies present beneath the leaves; nymphs of winged viviparous females present; some of the leaves are crinkled along the veins showing a slight damage due to the aphids; there are however not very many aphids produced, and the infestation is only moderate.

Plant No. 24. *Onions.*

18. 6. 13. Infected from Euonymus tree growing in Acton Lodge garden with four w. v. ♀'s.

28. 6. 13. Aphids all dead.

Experiments. Series B.

In this series of experiments, the writer wished to find out if the winged migrants from Euonymus showed any preference for particular plants, if a choice of food plants were given.

It was desirable that the aphids should, as far as possible, be under natural conditions. At the same time it was necessary to ensure against infection from other plants, and that the plants should be grown under conditions which enabled constant observations to be made.

For these reasons, a wooden framework, 33 feet long, 6 feet wide, and 5 feet 6 inches high, was erected over a plot of ground in Acton Lodge garden. This was covered with very fine muslin which was carefully fastened down to the woodwork so that insects could not get in or out. The tent was divided into three compartments by muslin partitions, so that the insects could not pass from one compartment to the other.

Early in April the plot of ground surrounded by the tent was heavily fumigated with carbon di-sulphide. At the end of this month several food plants which had been raised in pots from seed were placed in the tent, and in addition, some seeds of Broad Beans, Shirley Poppies, Mangolds, etc. were sown.

In Compartment *A*, the following plants were grown: Broad Beans, Shirley Poppies, *Papaver rhoea*, Mangolds, Red Beet, Sugar Beet, Swedes, Onions, *Rumex sanguineus*, Nasturtiums.

In Compartment *B*, Broad Beans, Shirley Poppies and *Papaver rhoea*.

In Compartment *C*, Broad Beans and *Rumex sanguineus*.

Each compartment was entered by a door which opened from outside into each compartment separately.

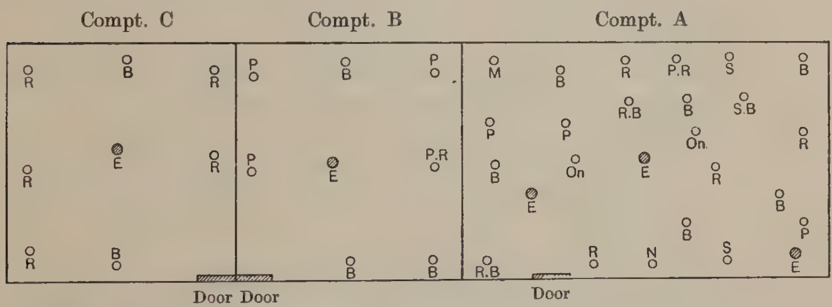
At the beginning of June (3. 6. 13), Euonymus bushes which had been infected in May with *Aphis rumicis* from the Euonymus bush *B*,

referred to in series *A*, were placed in the tent. These bushes had been kept covered with muslin, and although the number of aphids produced on the bushes by this date was very few, several healthy colonies were present on them. The plants in the tent were carefully examined before the infected bushes were introduced, and were found to be quite free from aphids. They were very clean and healthy, and owing partly to shade afforded by the muslin, and partly to the effect of the fumigation, they were making splendid growth.

Owing to the colony of Aphids on the Euonymus bush placed in the Compartment *C* not developing, no infestation of *A. rumicis* occurred in this compartment, consequently no results were obtained.

After the Euonymus bushes were placed in the tent, the plants were kept under close observation and notes made from time to time. These notes are given below, with the dates when the observations were made. They show the results obtained, and indicate the progress of the infestation of the different plants by the winged migrants from the Euonymus bushes.

The following plan shows the arrangement of the food plants in the different compartments.



General plan indicating the general arrangement of the food plants in the tent.

P.=Shirley Poppies; *B.*=Broad Beans; *R.B.*=Red Beet; *S.B.*=Sugar Beet; *E.*=infected Euonymus bush; *M.*=Mangolds; *S.*=Swedes; *R.*=*Rumex sanguineus*; *N.*=Nasturtiums; *P.R.*=*Papaver rhoea*; *On.*=Onions.

Compartment A.

3. 6. 13. Euonymus bushes infected from Euonymus *A*, placed in the tent.

28. 6. 13. Some winged viviparous females have now migrated from the Euonymus to Broad Beans, and a few colonies of lice are produced on these plants.

3. 7. 13. Aphids now infesting the Broad Beans in fair numbers, and many colonies are present on the flower-stalks and tips of the young shoots.

A few small isolated colonies present on the veins beneath the leaves of the Rumex plants, but very few in numbers. One Rumex plant which is producing a tall flowering head has a number of colonies on it.

The other plants not infected.

14. 7. 13. The aphids are heavily infesting the Broad Beans, and appear to have all left the Euonymus bushes.

A few isolated, small colonies on the Rumex leaves. I found one winged viviparous female on the Poppies, but no colonies forming yet on these plants.

Many winged viviparous females are produced, and a number are walking on the roof of the tent as though wanting to escape.

A few aphids present on the leaves of the Red Beet, but numbers very few.

Other plants not infected.

22. 7. 13. The Broad Beans are very heavily infested, although some of the plants still have plenty of young growth to afford food for the aphids. Many of the young pods are heavily infested with the aphids, and the colonies have extended to about half-way down the stems in some cases. Many colonies also beneath the leaves, and the winged females present on these plants chiefly settle below the leaves, although several are also on the stem.

A few colonies are now forming on the Poppies being chiefly collected along the flower-stalks, but some also on the stems and beneath the leaves.

There are a few colonies on the Red Beet and Sugar Beet, but very few in number. Some of the Red Beet leaves are crinkled along the veins, which seems to be due to the action of the aphids.

Several of the Rumex plants have a few colonies, consisting of a small number of individuals, present on the underside of the leaves.

I found one or two small colonies of apterous forms present on the Euonymus bush, but the aphids seem to have practically all left these plants.

There are no aphids on the Swedes, Nasturtiums and Onions.

10. 8. 13. The Broad Beans in many cases are almost smothered with aphids, the underside of many of the leaves being almost covered with them. They are also in great numbers on the young pods. The terminal shoots of these plants are brownish in colour and dying off.

The Shirley Poppies are now fairly heavily infested, and there are many winged viviparous females and nymphs on them. The aphids are to a great extent collected along the flower-stalks, towards the flower-heads, but also some along the stems and beneath the leaves. There are several colonies also present on the *Papaver rhoea* plants.

There are a few isolated colonies, small in number, present on the Red Beet and Sugar Beet; and a very few aphids on the Mangolds, but in this latter case only a small isolated colony on a very few leaves.

Several small colonies present beneath the leaves of the *Rumex sanguineus* plants. There is a great deal of Rumex present so that the colonies are widely distributed.

There are no colonies forming on the Swedes.

10. 10. 13. The Broad Beans, Poppies, and Nasturtiums have all died down. Beet, Mangolds and Swedes are growing well, and look healthy. Aphids seem to have all disappeared, having died off, and only an isolated individual to be seen here and there.

Compartment B.

3. 6. 13. Euonymus bush infected with *Aphis rumicis* from Euonymus *B* placed in this compartment.

3. 7. 13. Winged viviparous females have been produced on the infected Euonymus bush, and several winged forms have migrated to the Broad Beans where they are forming colonies.

14. 7. 13. Broad Beans now fairly heavily infested, and a few small colonies are also going on the Poppies.

22. 7. 13. The Broad Beans are heavily infested. Colonies forming rapidly on the Shirley Poppies. The aphids have all left the Euonymus bush.

10. 8. 13. The Broad Beans and Shirley Poppies are now heavily infested. *Papaver rhoea* plants also attacked, and many of the leaves are curled and clustered together owing to the aphids. The Shirley Poppies are especially infested along the flower-stalks.

10. 10. 13. The Poppies and Beans have now died down. The aphids seem to have all disappeared, having died off. An isolated winged form here and there on the dead plants. No aphids on the Euonymus bush, which is growing fast.

Compartment C.

3. 6. 13. Euonymus bush infected with *Aphis rumicis* from Euonymus *B*, placed in this compartment.

The colony is very small, and does not seem to be making any progress.

3. 7. 13. One small colony on the Rumex plants. The aphids on the Euonymus bush are small in size and numbers, and do not appear to be going well.

14. 7. 13. No aphids on the Broad Beans. The aphids present on the Euonymus bush are not making any progress.

10. 8. 13. No aphids on the Euonymus bush. A few winged viviparous females present on the Broad Beans, but only a few small colonies formed.

10. 10. 13. The Broad Beans have died down.

Experiments. Series C.

This series of experiments consists of observations made on plants grown in the open garden at Acton Lodge. Many different kinds of plants and vegetables were cultivated in various parts of the garden, and weeds were also allowed to flourish in order that observations might be made on the migration of the winged forms of *Aphis rumicis* from Euonymus.

On May 24th, three small Euonymus bushes found near Richmond, heavily infested with *Aphis rumicis* (*euonymi*), were introduced into the garden at Acton Lodge. There were great numbers of winged forms on these bushes at this time.

The following notes recorded below will show how the aphids became distributed to many of the plants growing in the garden. The dates given do not denote the exact date when the plants became infected, but the date on which the observations were made. It may be noted, however, that in the case of the Broad Beans, *Aphis rumicis* was not found on these plants until the date given below. The infestation of these plants occurring so quickly after the introduction of the infected Euonymus bushes (one bush was placed close to a row of Broad Beans) leaves little doubt that the infection came from Euonymus. By the middle of June, practically all the aphids had left the infected Euonymus bushes.

Date	Host Plant	Remarks
24. 5. 13.	*Euonymus europaeus* ..	Three bushes heavily infested with *Aphis rumicis*, introduced into Acton Lodge garden; many winged viviparous females present. These had all migrated by the 30th May, and by the middle of June the bushes were quite free from aphids.
25. 5. 13.	Broad Beans	Many winged females present and several colonies forming.
29. 5. 13.	Broad Beans	Many colonies now developing on these plants.
29. 5. 13.	*Euonymus europaeus*	Found several winged viviparous females on some large Euonymus bushes in Acton Lodge garden, and colonies are being produced on these bushes.
1. 6. 13.	Spinach	Several plants infected and colonies forming on them, along the stems and flower-heads.
1. 6. 13.	Parsnips	Some old Parsnip plants which are running to seed are now infected, and colonies forming in the flower-heads.
2. 6. 13.	*Rumex*, sp.	Several plants now infected, one plant near the Broad Beans being especially heavily infected.

13. 6. 13.	Scarlet Runner Beans	*Aphis rumicis* forming colonies on the tips of the young shoots, and a few colonies beneath the young leaves.
13. 6. 13.	Spinach.	A few plants near the infested Broad Beans are now fairly heavily infested.
13. 6. 13.	Red Beet	A plot of Red Beet plants near the Broad Beans have now several colonies on them, and some of the leaves are crinkled along the veins which is probably due to the presence of the aphis. The colonies are forming along the veins beneath the leaves, but only a few leaves infected. Another plot of Red Beet at some distance from the Broad Beans is not infected.
13. 6. 13.	Onions	A few individuals are present on a few plants; they seem to wander to the top of the leaves. Found a few lice produced on these plants, but in a few days the aphids disappeared from the plants.
23. 6. 13.	Red Beet	Several plants infected. The aphids have collected chiefly on the very young leaves, near the base of the mid-rib, and along the veins. These plants are however only slightly infected.
23. 6. 13.	SugarBeet	Only a few aphids present on these plants.
23. 6. 13.	Mangolds	A very few leaves with one or two small colonies present.
23. 6. 13.	*Atriplex hortense* ..	These plants are now growing tall, and several colonies of aphids are present along the young parts of the stems.
3. 7. 13.	Peas	A few small colonies present on the young terminal shoots.
3. 7. 13.	*Carduus* sp.	A few of the plants in a large plot of thistles are heavily infested along the stems.
3. 7. 13.	Tomatoes	A few individuals generally distributed over these plants, but the aphids do not seem to be forming colonies.
3. 7. 13.	Scarlet Runner Beans	Several plants fairly heavily infected, the aphids forming colonies on the young terminal shoots, and some along the mid-ribs beneath the leaves. There are several small colonies present on the leaves of the Dwarf French Beans.
4. 7. 13.	Asparagus	These plants have now grown big and bushy, and many colonies of *Aphis rumicis* are present on them; nymphs of winged females are produced.
4. 7. 13.	*Capsella bursa-pastoris*	Several Shepherd's purse plants are infected, the colonies forming along the apex of the stems at the base of the flower-stalks.
4. 7. 13.	*Chenopodium album* ..	There are many small Chenopodium plants fairly heavily infested. The colonies are present chiefly along the veins of the leaves, which make the leaves curl. Several nymphs of winged females produced.

4. 7. 13.	*Urtica* sp.	A small species of nettle, about a foot high, is infected. The colonies are forming along the apex of the stem and along the mid-rib of the leaves, causing the terminal leaves to cluster together; nymphs of winged females are present.
4. 7. 13.	Dahlias	One Dahlia plant has two or three large colonies of big apterous females on it. The aphids are collected along the flower-stalks, towards the base of the flowers.
18. 8. 13.	Nasturtiums	These plants are growing beneath the Dahlias. The aphids have now left the latter plants, and there are several colonies present on the Nasturtiums.
— 9. 13.	*Chenopodium* sp. ..	A few of these plants are still infested with aphids.
— 9. 13.	*Urtica* sp.	A few aphids still present on these plants.

General Conclusions.

The general results obtained in these experiments have already been indicated in the notes given about the various plants.

It is seen that, in the experiments, series *A*, as the different generations of winged migrants were produced they were transferred to different host plants. It was thought the previous plant host upon which the aphids were produced might have an influence on the degree of infestation of the succeeding host plants to which the winged migrants were transferred. The results obtained do not, however, give sufficient evidence of this. It will be necessary to carry out this experiment with a large number of plants, the number of aphids produced on the different plants in a specified period of time being counted. Further, it will be necessary to find the variation in the number of aphids produced on different plants of the same species, for the purpose of comparison, before definite conclusions can be drawn.

The Euonymus bush *A* (series *A*) became heavily infested with *Aphis euonymi* in February by the rapid reproduction of the original small colony. The bush had been put into the greenhouse and the sheltered conditions no doubt favoured this rapid reproduction.

The Euonymus bush *B* which was infected with winged viviparous females from *A* did not become heavily infested until several weeks had elapsed, although by the middle of May it was almost smothered with the aphids.

The third set of Euonymus bushes which were infected from Euonymus *B* early in May had only a few small colonies on them by the beginning of June. On the third of this month they were placed in the muslin tent and although winged forms were produced towards

the end of June the numbers of aphids produced on these bushes were very small. In fact the colony on the Euonymus bush placed in the compartment *C* of the tent made little or no progress, so that results were not obtained for this compartment.

Now if we compare these results with what happened in the tent when the winged migrants settled on the Broad Beans, we find that in two or three weeks these latter plants became very heavily infested by the rapid reproduction of the aphids feeding on them.

Also in series *A* the Rumex plants, Broad Beans, and Poppies infected from Euonymus *B* with winged viviparous females became heavily infested in a few weeks.

The plants in series *A* were all infected with winged viviparous females, with the exception of Rumex No. 2, which was infected with apterous viviparous females. Winged forms were used because it is the winged migrants which infect new host plants. It will be seen, however, that the apterous viviparous females from Euonymus flourished and reproduced in great numbers when transferred to *Rumex sanguineus*, winged migrants being produced in due course.

A noticeable feature throughout the experiments was the migratory tendency of the winged viviparous females. Soon after the winged generation was produced on the various plants, the winged forms showed a desire to migrate and collected in vast numbers at the top of the muslin bags which covered the plants. They seemed active and restless, and apparently not feeding on the host plant on which they were produced. However, many undoubtedly produced "lice" on the host plant, and several could usually be found sitting beneath the leaves, but the majority of the winged forms crowded round the top of the muslin cover, even when the host plant was still in a healthy condition. When the top of the cover was opened they immediately took flight.

It would appear from these observations that the winged females demand a change of host plant, and it is for this reason that certain plants which may be heavily infested early in the summer suddenly become free from aphides, owing to the production of winged migrants which, when they are produced, tend to leave the original host plant. In the case of *Aphis euonymi* I found hundreds of young nursery Euonymus bushes smothered with these aphids in May, whereas a few weeks later the bushes were almost free from them. Two or three of these bushes were kept under close observation. On May 23rd, they were heavily infested with *Aphis euonymi*, many winged forms being present. A week or so later the bushes were almost free from these aphids, and

the winged migrants had gone to Broad Beans, on which plant they were reproducing rapidly.

This brings us to the important question, What are the factors underlying the production of winged forms and the consequent migratory habits of Aphides ? The migratory instincts of the winged females may underly the desire to escape from the original host plant, but it may be that a change in the constitution of the cell sap of the host plant, which affords the food of Aphides, has an influence on the production of winged forms and the consequent migration of the Aphides from the original host plant.

In the case of the Euonymus bushes *A* and *B* (series *A*), when these bushes became very heavily infested, being practically smothered with aphids, both the winged viviparous females and the apterous forms became surprisingly active and ran over the bushes and muslin cover in a most restless manner as though wishing to escape. Moreover, they became considerably reduced in size, both apterous and winged forms being very much smaller than those produced on the Broad Beans and Rumex plants. In the latter stages of the heavy infestation of the Broad Bean plants, the aphids on these plants were also much smaller than in the early stages of infection. It may be that owing to the pathological condition of the plants induced by the heavy infestation, the aphids were unable to obtain sufficient food, but there is the fourth question of the change in the constitution of the cell sap brought about by the heavy infestation of the plants.

Woodworth, C. W. (1908)[1], who made some observations on *Aphis brassicae*, states that when a plant wilts the birth rate decreases and suggests that the failure of plant lice to develop winged forms under favourable conditions is due to the rapid development of the rest of the body. He refers to a paper by Clark in the *Journal of Technology*, Vol. I (which, unfortunately, I have been unable to consult), who obtained winged forms of *Macrosiphum rosae* in the first generation, by rearing the aphids on rose-cuttings grown in sand wetted with a solution of magnesium salts.

During the summer of 1913, I carried out a number of experiments with *Macrosiphum rosae*, on rose-trees grown in soil treated with definite quantities of various inorganic salts. I regret that owing to the extraordinary numbers of aphids that were produced, and the confusion resulting from this, that the experimental error is too great to allow

[1] Woodworth, C. W. (1908), *Entom. News*, Philad. 1908, XIX, pp. 122–3.

of conclusions being drawn from them. It is intended to repeat these experiments, making the necessary alterations to avoid error.

During the summer of 1911 a young apple tree infected with *Schizoneura lanigera* Hausm. was kept under observation in a greenhouse. The aphids reproduced in great numbers, the leaves began to wilt, and the tree looked very sickly. In the later stages of the attack, winged viviparous females were produced in vast numbers, and most of them left the tree and collected on the woodwork of the greenhouse. Later, all the leaves on the plant died, and although there were several " living " branches the aphids practically all died off.

The winged forms of *Schizoneura lanigera* are not common in England, and it would seem that the heavy infestation produced some change in the constitution of the cell sap, which induced the production of winged migrants. When a plant becomes so heavily infested that the leaves begin to wilt and the green parts are smothered with aphids, the normal green surface of the plant which carries on the processes of photosynthesis is considerably reduced in area and as a result the constitution of the cell sap is probably changed.

It is a well-known observation that aphids prefer the young growing shoots of the plants they attack. They readily select the parts of the plant which afford the best supply of sap.

In early summer, rose-trees frequently become infected with *Macrosiphum rosae*, the aphids collecting on the young stems and terminal shoots, where they reproduce in great numbers. Later on in the season, the trees are often quite free from these aphids.

During the summer of 1913, one rose-tree in Acton Lodge garden was kept covered with a muslin cage. The tree was covered early in the summer and infected with *Macrosiphum rosae.* The colonies increased in great numbers on the young terminal shoots, and along the petioles of the flower buds, and soon the plant became very heavily infested, vast numbers of winged forms being produced. Many of the leaves died and the young terminal shoots looked very sickly. Later on practically all the aphids died off. The tree then began to make new growth later in the summer. These young shoots soon became infected and the aphids reproduced in great numbers on them.

It was noted in the case of the rose-tree experiments mentioned above, that at first the aphids collected on the young terminal shoots, or along the petioles of the flowers, just beneath the buds. When the flower buds were cut off, the aphids very soon left the petioles and went to another part of the plant. Gradually as the numbers

increased, they distributed themselves beneath the leaves, along the mid-ribs, and secondary veins, and, finally, practically the whole plant in many cases became smothered with the insects. At this stage, both the apterous and viviparous forms became active and restless and ran over the plant as though wishing to escape. Many of them left the plants and died on the soil in the pots.

From these observations, it would appear that at different periods of the growth of plants, a change in the quality or constitution of the cell sap occurs which renders it unsuitable for the aphids. Further, the pathological condition of the plants, induced by heavy infestation, no doubt causes considerable changes in the constitution of the cell sap.

When Broad Beans are infected with *Aphis rumicis*, the young terminal shoots are first infested, the aphid colonies gradually extending down the stem, and on the veins below the young leaves.

From an examination of sections through the stems and leaves of some plants, which were infested with aphids, one sees that the stylets are forced through the epidermis and pass intracellularly between the cells of the plant tissues towards the phloem cells of the vascular bundles. The stylets often pass in a very irregular manner between the cells of the cortex, and are not forced into the plant in a direct straight line.

From a recent study of the mouth parts and mechanism of suction in *Schizoneura lanigera*, which the author has recently carried out, it has been shown that the plant juices pass up to the pharynx through a very minute suction canal formed by the partial fusion of the two internal stylets[1]. This canal is extremely minute in transverse section, and it is highly probable that the ascent of the sap through it is largely due to capillarity.

This is an important point for consideration. It is obvious if the surface tension of the cell sap is such that it cannot ascend up the minute capillary tube the aphids would be unable to obtain food. It is probable that in young growing shoots the stylets can be more easily forced into the plant tissues, but there is the question of the difference in the supply and constitution of the cell sap in young, actively growing parts of a plant. It is not improbable that in the case of small plants heavily infested with aphids, the cell sap is rendered toxic, or at any rate distasteful to the insects.

I have indicated that the individuals living on a plant very heavily infested with aphids become gradually smaller, and apparently derive

[1] This paper will shortly appear in the *Transactions of the Linnean Society*.

no nourishment from the host plant. This was seen in the case of the aphids on Euonymus, and on Broad Beans. It would be interesting to know if the pathological condition of the plants had an effect on the surface tension of the cell sap.

In the paper on the mouth parts of *Schizoneura lanigera*, referred to on the preceding page, there is described a "taste organ," which is situated near the entrance of the suction canal into the pharynx. It is very probable that by means of this organ the aphids are able to appreciate changes in the quality of the cell sap, although owing to the extreme minuteness of these mouth parts it is almost impossible to demonstrate its function practically. That the aphids become restless and dissatisfied with their hosts at different periods of the plant's growth, or when the plant is heavily infested, has been seen throughout these experiments as is indicated in the observations given.

As is seen in the case of the tent experiments, *Aphis rumicis*, under favourable circumstances, will select its host plant. Thus in the Compartment *A*, Broad Beans became first infected, then the Shirley Poppies and the other plants only became infected to a very slight degree.

Davis (1909), found that *Aphis maidis* Fetch, showed a decided preference for broom corn plants over Indian corn and Sorghum[1].

It is an interesting feature of aphid habits, that one species may infest a number of different species of plants. This is the case with the species at present under consideration (*Aphis rumicis*). It is readily seen, however, that although this particular species of Aphis may live on a number of different species of plants, some of these plants are subject to a greater infestation than others.

It was observed that while Broad Beans infected with *Aphis euonymi* from *Euonymus europaeus* became rapidly infested by the reproduction of the aphids, Red Beet infected from Broad Beans did not become so heavily infested, although the few aphids produced appeared to be healthy.

Again, in all cases where Broad Beans and Shirley Poppies were infected with this species, the former plants became heavily infested sooner than the latter.

Further, it was noted that certain plants in the garden of Acton Lodge were infected with *Aphis rumicis*. On many plants, such as Broad Beans, *Rumex* sp. and *Chenopodium album*, the colonies reproduced in great numbers and in most cases gave rise to a more or less

[1] Davis, J. J. (1909), "Biological studies of three species of Aphididae," *U.S.D.A. Bur. Ent.* Techn. Ser. No. 12, pt. VIII, p. 146.

heavy infestation. On many other plants, however, although aphids were present, the colonies were small. The individuals looked healthy and happy, but the numbers produced were small, and the plants really never became heavily infested.

This would seem to show that the cell sap of certain plants affords a suitable stimulus for certain species of aphids, resulting in rapid reproduction of young, while on some other plants, although the cell sap may afford a suitable food for the specific aphids, the stimulus derived from it does not induce such a rapid reproduction of young.

There is the question that the quality of the sap in any particular species of plant may be subject to change according to the soil conditions in which it may be growing. I have not any particular reference to hand, but I believe work has been done, showing that by treating certain plants with chemical substances they may be rendered immune to a specific fungus attack. Mangolds and Beet have been recorded from time to time, both in this country and in France and Germany, as subject to infestation by *Aphis rumicis*. In some seasons, on the other hand, these plants may be more or less free from infestation.

In connection with this point, there seem to be two points for consideration. Firstly, whether the presence in the neighbourhood of these crops of food plants for which *Aphis rumicis* shows preference, afforded sufficient food for the aphids and so prevented an overflow to the Mangolds and Beet. Secondly, whether any special manurial treatment of the soil rendered the crop more susceptible to attack.

It would be interesting during such an outbreak, to tabulate the food plants found in the immediate neighbourhood. It does not seem at all unfeasible that in a very bad season, a "catch crop" might be sown; for example with *Aphis rumicis*, the aphids evidently prefer Broad Beans and Poppies if these plants are present.

Malanquin and Moitié (1913)[1] record heavy attacks of *Aphis papaveris* in 1911 on the Sugar and Cattle Beet in the North of France. They record the presence of the Aphis also on Spinach, Rhubarb, Poppies and Beans. These authors add that this Aphis leaves the seed plants about the middle of July because they do not afford sufficient food and go to the Sugar and Cattle Beet.

Davis (*op. cit.* p. 132) observed with *Aphis maidi-radicis* that when food supply was scarce, the tendency was for winged forms to be produced.

[1] Malanquin, A. and Moitié, A. (1913), "Le Puceron de la betterave dans le nord de la France," *La Vie Agricole*, II, No. 24, pp. 696–699.

Throughout my experiments it was observed that, when the plant had finished its young active growth, or became heavily infested with aphids, the changes resulting either in the quality or quantity of the cell sap (or both) seemed to induce the production of winged forms, which wanted to migrate to other plants.

It may be that in the case of the Compartment *A* in the tent, the Shirley Poppies and Broad Beans afforded sufficient food, and thus the Mangolds and Beet did not become heavily infested.

Gaumont (1913)[1] records a heavy infestation of Beet by *Aphis euonymi* in the South of France during 1911.

Theobald (1912, p. 471, *op. cit.*) records migration flights of *Aphis rumicis* in the South of England during 1911. Poppies became very heavily infested, and then when these became "seedy," masses of winged migrants were distributed over many different plants, but only on Dahlias, Beet, and Mangolds did they flourish to any great extent.

It would seem that under natural conditions winged migrants of *Aphis rumicis* are produced on the host plant, and they take flight, being carried partly by their own powers of flight, partly by the wind, to many different species of plants. On some plants such as with Onions in these experiments, they soon die off, on others they live happily, and form small colonies, while on others they reproduce in enormous numbers and heavily infest the plants. In the latter case, it would appear that the cell sap is best suited for the particular species of Aphis and affords the necessary stimulus for the rapid reproduction of young.

It remains yet to be proved whether the stimulus derived from the cell sap of the previous host plant has any influence on the degree of infestation of the succeeding host plant.

Some seasons are much more favourable than others for the distribution of aphids. The present season of 1913 has been a particularly favourable one for Aphis "blight[2]." Winged aphids are very fragile, and, if the weather conditions are wet and severe, the winged migrants are unable to withstand the journeys from plant to plant.

In favourable seasons the distribution of aphids over a district from plant to plant may be very extensive.

[1] Gaumont, L. (1913), "Le Puceron de la betterave," *Revue de Phytopathologie*, I, No. 1, April 20th, 1913, pp. 12–13.

[2] *Gardeners' Chronicle*, London, 7th June, 1913, p. 377.

SOME OBSERVATIONS ON THE LIFE-HISTORY AND BIONOMICS OF THE KNAPWEED GALL-FLY *UROPHORA SOLSTITIALIS* LINN.

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(With Plates XI and XII and 1 Text-figure.)

CONTENTS.

Introduction.

In September 1911, whilst collecting seeds of wild plants at Prestatyn, North Wales, I found galls in many of the flower-heads of the small knapweed, *Centaurea nigra* L., and these on further examination were found to contain dipterous larvae.

On counting the seeds contained in a few of the galled flower-heads, and comparing the numbers obtained with the numbers present in ungalled heads, it was seen that considerably fewer seeds were present in the former than in the latter It therefore seemed probable that

the dipterous larvae present in the flower-heads, by inducing gall-formation, caused a reduction in the number of the seeds normally produced by this troublesome and useless weed, which is very common in many pastures and meadows.

A number of the infected heads were brought to Manchester, and kept until the following spring, when, towards the end of June, imagines commenced to emerge from the galls, and continued to do so during the ensuing three weeks.

The fly was recognised as a Trypetid and specimens for determination were submitted to Mr J. E. Collin, of Newmarket, to whom I am indebted for naming them ; they belong to one of the common species of Trypetidae, viz. *Urophora solstitialis* L. Mr Collin also informed me that so far as he knew the larvae and pupae of this species had never been scientifically described.

Early in July some young flower-heads of the knapweed were gathered and a few fertilised female flies were placed on them in a covered glass jar. The females deposited eggs freely, and in eight days from the date of oviposition free larvae were observed within the flower-heads. It was thus apparent that the flies would breed freely in captivity, and Professor Hickson suggested that I might undertake a study of the life-history of this species.

The work was carried out in the Department of Agricultural Entomology of the Victoria University, Manchester, and I wish here to thank Professor S. J. Hickson for his kindness in providing me with opportunities by which I have been enabled to undertake this research ; to Dr A. D. Imms my thanks are also due for valuable suggestions and advice given during the later stages of its progress, and to Professor F. E. Weiss for permission to use apparatus belonging to the Botanical Department. My indebtedness to others who have assisted me in various ways, is acknowledged in the text.

Description of fly and classification.

The fly was described by Linnaeus (1758) under the name *Musca solstitialis* ; since then it has been frequently referred to and more fully described, under various names, by several entomologists. Loew (1844) discussed the characteristics of this species very fully, and he recognised and described five well marked size and colour varieties. In his monograph *Die europaischen Bohrfliegen* (1862) the same author gives a full description of the species, together with the synonomy ;

the description given by Schiner (1864) is more complete however, and of this the following is a slightly abbreviated translation.

"Wings yellowish-white, with brown bands, of these the first and second are always widely separated at the anterior border. Body glossy black; thorax with a brownish-yellow dusted appearance, and with the usual yellow side-stripes as in *Ur. stigma*; scutellum yellow, blackish at the sides. Ovipositor much longer than the abdomen, and swollen from the base to the middle. Head yellow, posterior aspect black or brown; facial aspect paler, frons distinctly brighter in the centre, sometimes rusty-yellow. Antennae, proboscis, and palps, reddish-yellow; proboscis lobes rather narrow, and much elbowed backwards. Legs yellow, in most specimens the anterior femur with a black stripe on the outer border, less frequently a similar stripe is present on the mid and hind femora; terminal tarsal joints brown. Wings with a yellowish-white tinge; at the base and towards the anterior border as far as the stigma, a deeper yellow, with four lighter or darker brown moderately straight cross bands. The first lies near the wing base, is frequently indistinct, and reduced, but always present; it extends backwards at the most into the anal cell, and is always widely separated from the second band. The second proceeds from the point of the brownish-yellow stigma over the discal cross-vein, almost completely straight to the posterior wing-border; the third arises at the anterior wing-border in front of the apex of the marginal cell and proceeds moderately straight over the posterior cross-vein to the posterior wing-border; the fourth is usually narrowly continuous with the third anteriorly, and borders the wing-tip just beyond the fourth longitudinal vein. The clear area between the second and third bands is at least double the width, or frequently only just wider than, the bands themselves. Examples are found in which the bands are very much faded, their position, however, is always distinctly recognisable. Discal cross-vein a little beyond the middle of the discal-cell; 3·1—6·2 mm."

Bezzi (1910, 1913) has recently proposed that the family name should be Trypaneidae instead of Trypetidae, by which name this family of acalypterate flies has been known so long. He divides the family into two sub-families, the Dacinae and the Trypaneinae; the latter is divided into three tribes, Ceratitininae, Myiopitininae, Trypaneininae. The second tribe contains only three genera: *Myiopites* (*Stylia*), *Asimoneura*, and *Urophora*.

Among other characteristics of the tribe Myiopitininae are the

following: "the species are found exclusively in temperate countries, being wanting in the tropics; the larvae live only on plants of the family Compositae, and often make galls" (Bezzi).

The genus *Urophora* was proposed by Robineau-Desvoidy in 1830, one of many that he formed out of the large genus *Trypeta* of Meigen, and from this date onwards the name of the species *Urophora solstitialis* Linn., has been accepted by most entomologists.

The following is a list of the principal synonyms of the species as given in Loew's monograph.

Urophora solstitialis Linn. (1758) ♂ and ♀.

Musca solstitialis Linnaeus, Syst. Nat. x. 601, 98. Faun. Suec. II. 1879. Syst. Nat. XII. 999, 127.
Musca Dauci Fabricius, Mant. Ins. II. 353, 118. Ent. Syst. IV. 358, 187.
Musca solstitialis Cederhjelm, Prod. 318, 1006.
Dacus Dauci Fabricius, Syst. Antl. 277, 22.
Dacus hastatus Fabricius, Syst. Antl. 276, 15.
Trupanea Leucacanthi Schrank, Faun. (Boic.) III. 141, 2507.
Tephritis solstitialis Fallen, Ortal. 6, 5.
Trypeta solstitialis Meigen, Syst. Beschr. v. 324.
Trypeta pugionata Meigen, Syst. Beschr. 330.
Urophora solstitialis Walker, Ent. Mag. III. 7 (ex parte) Macquart, Suit. Dipt. II. 457, 9.
Trypeta solstitialis Loew, Germ. Zeitschr. v. 355.

Geographical distribution.

Urophora solstitialis has been recorded from nearly all the countries of Europe; a list of these records is given by Schiner (1858). Mr J. E. Collin informs me that it is common and widely distributed in England; Fitch (1872) records it from Suffolk; Wingate (1906) from Hesleden, Durham; Connold (1901) from Hastings, Sussex. I have collected the galled flower-heads containing larvae of this species at Prestatyn, North Wales, and also at Port Erin, Isle of Man; and Dr A. D. Imms collected a few galled-heads at Llwyngwril, Merionethshire. Professor J. W. H. Trail of Aberdeen very kindly sent me the following list of localities in Scotland where galled heads containing the larvae have been obtained: Aberdeenshire and Kincardineshire, especially in the valley of the Dee; near Dunkeld and elsewhere in the valley of the Tay, from Glen Falloch, and from Loch Lomond in Perthshire; in these and in other localities the galls are abundant. I am indebted to Professor G. H. Carpenter of Dublin for a note on its occurrence in Ireland;

it has been recorded from Ballyvaughan, Co. Clare; Westport, Louisburgh and Clare Island, Co. Mayo. Professor Carpenter further remarks that probably the species is widely spread in Ireland.

It is worthy of note that specimens belonging to the genus *Urophora* have been recorded only from the old world. In the *Katalog der Paläarktischen Dipteren* (1905) twenty-nine species of this genus are recorded from Europe and Northern Africa; seven of these are listed as British (Verrall) and one species, *U. spoliata* Hal., has not been found elsewhere.

Historical.

Records of detailed observations on the life-history of this species appear to be very scanty, although a few well-known entomologists have studied closely allied forms. Thus Goureau (1845) described the larva and pupa of *U. cuspidata* Meig., and Dufour (1857) those of *U. quadrifasciata* Meig. Until comparatively recently the former was regarded as synonymous with *U. solstitialis* (Schiner, H. Loew); Becker (1902) however, who examined Meigen's type of *U. cuspidata* in the Paris Museum, considers that *U. cuspidata* Meig. is distinct from *U. solstitialis* L. The most complete account of the larva and pupa of a species of the genus *Urophora* was given by Mik (1897) who described those of *U. cardui* L.; the larvae of this species induce galls on the stems of *Cirsium arvense* L.

Boie (1848) obtained *U. solstitialis* in hundreds from galled flower-heads of *Carduus crispus* L.; they emerged from June 8 to July 12. From several thousand pupae only three or four flies emerged in autumn, and his opinion was that this species gave rise to a single brood only, unless exceptional conditions prevailed.

In a paper devoted to the natural history of the Trypetidae, Frauenfeld (1857) refers to this species among others; he states further, that it produces swellings in the receptacles of all the plants that it infects, and he gives a list of its food-plants.

There is a brief paragraph by Kaltenbach (1874) on this species, he gives the names of three hymenopterous parasites reared by Goureau from *U. cuspidata*, as parasites of *U. solstitialis*. He assumed, however, that the two latter were one and the same species.

Fitch (1872, 1879) refers to it in two short notes; it is also referred to by Connold (1901) and by Swanton (1912). Connold gives a short description of the galls together with photographs of these and of the larva and pupa.

Food-plants.

As regards the food-plants Schiner (1858) remarks that:

"The larvae live in the flower-heads of *Carduus nutans* L., *crispus* L. and *acanthoides* L.; they are also found in those of *Cirsium lanceolatum* L., *Centaurea scabiosa* L. and *montana* L., and on other Cynaroideae"; F. Löw (1866) recorded *Centaurea paniculata* L., as a food-plant of the larvae, and Fitch (1872) recorded this species from galled flower-heads of *Serratula tinctoria* L., collected in Suffolk. In a later paper (1879) this observer remarks that in 1872 he added to the list of [British] gall-making Trypetidae, *Urophora solstitialis* L., "which deforms the ovary of the common knap-weed (*C. nigra*) into a hard, woody, but only tactilely noticeable gall."

This is the first record which I have been able to find of the occurrence of this species on *Centaurea nigra*. Curtis (1860) refers to *U. solstitialis* under the name *Tephritis solstitialis* as being abundant on thistle blossoms during the summer, he does not state, however, that he bred the fly from thistles. Connold (1901) and Swanton (1912) both give *C. nigra* as the food-plant of the larvae of this species; Prof. Trail informs me that in Scotland *C. nigra* alone is known as the food-plant.

It is noteworthy that none of the continental authorities, whose writings I have been able to examine, record *Centaurea nigra* as one of the food-plants of these larvae; on the other hand, with the single exception of Fitch's record of *Serratula tinctoria* referred to above, all the records of its occurrence in this country that I have been able to consult, state that *Centaurea nigra* is the food-plant of the larvae here.

Many of the recorded continental food-plants are equally common in this country, whilst *Centaurea nigra* is common on the continent, and it is worthy of remark that there appears to be this difference in the habits of the larvae here and abroad.

The larvae of a closely related species, *Urophora quadrifasciata*, are recorded as feeding in the flower-heads of *Centaurea nigra* (Loew, Schiner); and according to the account of Dufour (1857) the life-history of this species and the effects produced by the larvae on the host-plant, are very similar to those of *U. solstitialis*.

There was just the possibility therefore, that I might be dealing with this species (*U. quadrifasciata*). Through the kindness of Mr J. E. Collin, I have had the opportunity of examining two continental specimens of *U. quadrifasciata* from Bigot's collection, and there is no doubt that the specimens reared here from *Centaurea nigra* are distinct from

the continental specimens of *U. quadrifasciata* that I examined. Possibly in this country *U. solstitialis* feeds also in the flower-heads of various species of thistles, and its occurrence in these food-plants may have been overlooked.

U. quadrifasciata differs from *U. solstitialis* in the following characters. Its average size is smaller. The thorax appears almost black owing to the very slight yellow powdering (Bestäubung) on the surface; all the femora are black also. The ovipositor is not much longer than the abdomen. The four cross-bands on the wings are very broad, dark, and sharply defined; the first band is united with the second, and the third with the fourth at the anterior border of the wing.

Life-history, description of ovipositor, and method of oviposition.

A supply of galled flower-heads was gathered in September, 1912, and one or more of these were examined from time to time in order to find out when pupation commenced. The first indication of change was observed on April 29th, the following spring; in one gall, two larvae were found whose skins were just hardening and changing to a darker colour. On May 3rd, ten individuals were found in one gall, and in nine of these the puparium was hard and definitely formed, whilst the remaining one was still in the larval state. From this date onward pupae were invariably found and in increasing numbers; the latest date on which I found unchanged larvae was May 29th. On June 1st imagines appeared; we may therefore say that the pupal state lasts from four to five weeks.

From June 1st imagines emerged every day until July 3rd; after this date very few emerged and only at intervals of several days, and the last fly emerged towards the end of July. The period of emergence thus extended seven weeks, but the greatest number of flies emerged during the month of June.

The flower-heads from which the flies were obtained were kept inside a cool room during the winter, and in April they were taken into the warmer laboratory. Outside in the open fields, development would probably be slower and the flies would emerge later. In the open, however, flies are on the wing in mid-June.

The number of males and females that emerged between June 3rd and July 3rd, 1913, was counted in order to ascertain the proportion of the sexes to each other. Between these dates 152 male flies and 130 females was obtained. In the early part of June, many more

males than females emerged, but towards the end of the month, this disproportion in the sexes was decreased. Fitch observed that the males emerged before the females, but he only obtained twelve females and eight males; the numbers he dealt with are therefore very small. If the results obtained above should be confirmed by subsequent countings of greater numbers, they might be explained by supposing that the greater numbers of males produced and their early emergence are provisions for ensuring that as far as possible, all the females shall be fertilised.

Four days after emergence, two pairs of flies were observed in copulation, and another pair copulated five days after they emerged (June 5th and 6th). Probably several days intervene between copulation and oviposition, the exact length of time that elapses between these two acts was not determined.

When the female is ready to oviposit she selects an unopened bud; the bracts of this, however, are just beginning to open. If the flower-bud is suitable for the purpose, she is observed to move over it in various directions; at the same time the ovipositor is frequently protruded and inserted at various points between the bases of the scales; she is evidently selecting a suitable place for the insertion of her ovipositor. As soon as this is found she settles down, her head pointing towards the apex of the bud; the first joint of the ovipositor is then bent almost at a right-angle to the abdomen, and pushed between the bases of the lowest and outermost scales; whilst in this position the ova are placed within the flower-head.

If a flower-head which contains eggs is severed vertically into two halves, and carefully examined, the eggs will be found either in the space between the upper surface of the florets and the overlying bracts (Fig. 2) or between the florets themselves. In order to understand how the eggs are placed in these positions, the ovipositor, during the process of oviposition, may be rapidly severed from the abdomen with a sharp pair of fine scissors, and its position in the flower-head observed; or in a fortunate section of an infected flower-head the tunnel made by the passage of the ovipositor may be seen (Fig. 13). Evidence has been obtained by both these methods, and in order to explain the process of oviposition in a more complete manner, a short description of the ovipositor is inserted here.

The female fly possesses the usual corneous, pointed, three-jointed ovipositor which is characteristic of the three closely related families of acalypterate muscids, Trypetidae, Ortalidae and Lonchaeidae (Bezzi).

The first segment of the ovipositor (which appears as the terminal segment of the abdomen) is about 2·7 mm. long ; it is swollen anteriorly, being about 0·6 mm. across in this region, and it becomes narrower in the posterior portion ; near the distal end it is about 0·25 mm. in diameter. The walls are strongly chitinised and it is covered with numerous hairs.

The second or middle segment of the ovipositor is about 2·3 mm. in length, by 0·15 mm. wide along its whole length, and consists of a transparent flexible membrane in which a great number of small chitinous sclerites are partially embedded. This segment is capable of protrusion and retraction, like the finger of a glove.

Fig. 1. **Extended ovipositor of *U. solstitialis* from left side, × 15. 1, 1st segment of the ovipositor ; 2, 2nd, flexible segment ; 3, 3rd, piercing segment**

The third and last segment is the actual piercing portion of the ovipositor ; it is composed of chitin, is about 2·3 mm. long, and except at the extreme narrow tip is about 0·07 mm. in diameter. There are two sharp-cutting blades at the sides of the tip. This segment contains the terminal portion of the oviduct, which opens to the exterior near the tip. During the passage of the ova this segment probably expands slightly.

The ovipositor is extended by pressure, presumably by muscular compression acting on some of the body-fluids. If the swollen portion of the ovipositor is compressed with a pair of forceps, the flexible and piercing segments are readily everted, and they always assume a curved

position which they retain as long as the pressure is applied. The significance of this curvature will be apparent if we consider the structure of the flower-head and the act of oviposition.

As is well known, the young florets of composite flowers are protected by an involucre which is composed of numerous bracts or scales. In the flower-head of *C. nigra* these bracts arise just below the level of the receptacle, and this is the region selected by the fly for the insertion of its ovipositor.

During oviposition the blunt end of the first segment of the ovipositor is placed between the lower scales as described above, and whilst in this position the piercing portion is forced into the tissue of the receptacle. The piercing segment passes downwards and inwards towards the vertical axis of the flower-head, and gradually bends upwards until the tip of the ovipositor finally reaches the space between the tops of the young florets and the overlying bracts. The ova are usually placed in this space; less frequently, however, they are to be found between the young florets. In the latter case the flower-heads are probably older than in the former case, and the florets are longer; consequently the ovipositor is not sufficiently long to reach the space wherein the eggs are usually laid.

Goureau, who correctly described the external appearance and movements of the ovipositor in *U. cuspidata*, believed that the ovipositor was pushed between the florets of open flowers, and that the eggs were then placed on the receptacle of the flower-heads. A similar opinion was also held by Dufour who observed some phases of the life-history of *U. quadrifasciata*. The latter observer, in addition, supposed that the eggs were placed inside the tissue of the receptacle, and further, he believed that the presence of the eggs, and possibly the injection of an irritating fluid at the same time as these were laid, induced "une irritation nutritive du réceptacle transformé alors en placenta"; in other words induced the formation of the gall.

Although the observations of these entomologists refer to species other than the one considered here, yet, as these species are all so closely related to each other, and their larvae also feed in similar flower-heads, it is almost certain that on this point the opinions of these observers were erroneous.

From evidence obtained by opening the flower-heads after oviposition and counting the eggs, and also by counting the number of larval chambers in galled heads, I believe the number of eggs usually laid at one time varies from one to four; where more than four eggs

or larval chambers are present they are probably the result of two or more separate acts of oviposition.

The ovaries of two females were dissected out and the eggs counted in order to determine the number of eggs a female fly is capable of producing. From the ovaries of a female which had laid no eggs, 108 apparently mature ova were obtained, as well as a considerable number of immature ones from the ovarian tubules; the ovaries and oviduct of another female yielded 105 ova; this fly had, however, laid a few eggs. We may safely say that a female of this species is capable of laying at least 100 eggs, and if the immature ova ripen as the season advances, then probably considerably more.

Descriptions of ova, larvae, and pupae.

The ovum of *U. solstitialis* is elongate and usually crescent shaped, with its widest diameter across the centre; the amount of curvature varies, however, examples are met with at times that are almost straight; from the central area the egg tapers towards each end, but more abruptly towards the posterior end which is pointed, than to the anterior or cephalic end which is rounded, and terminated by the prominent micropyle. Bezzi (1913), who discusses the metamorphosis and bionomics of the Trypaneids in general, states that the eggs are "rounded at the two ends"; the egg of this species is therefore exceptional in this respect.

The ova have a glistening white appearance, and when present are readily observed in the flower-heads; the shell or chorion is very thin and quite smooth, and exhibits no sculpturing or pattern on the surface.

In size the ova vary considerably: a number of ova laid by one female varied in size from $0{\cdot}87 \times 0{\cdot}15$ mm. to $1{\cdot}04 \times 0{\cdot}17$ mm.; ova taken from the same fly measured about $0{\cdot}9 \times 0{\cdot}12$ mm. The largest ovum observed measured $1{\cdot}3 \times 0{\cdot}15$ mm.; the average size is about $1\text{–}1{\cdot}02 \times 0{\cdot}15$ mm.

Just before deposition the fertilised ovum completely fills the space within the chorion, but shortly after oviposition the embryo commences to diminish in length; in three ova measured one hour after oviposition there was a shrinkage of 0·18 mm., 0·2 mm. and 0·3 mm. respectively, and within twenty-four hours of oviposition the embryo contracts to about two-thirds of its former length. (Fig. 7.) A space thus appears at each end between the embryo and the chorion.

The length of time that elapses between oviposition and hatching, varies somewhat; probably temperature is the controlling factor. In July 1912, larvae were obtained in eight days from the date of oviposition, whilst in June 1913, the shortest time recorded between these two events was eleven days.

The larvae, after hatching, may be found creeping on and between the florets; possibly they feed on these for a short time, but very soon they bore their way through the walls of the corollae and travel down the corolla tubes to the developing ovules. The corollae that contain larvae may be readily distinguished from those that are uninfected. Small circular or elliptical apertures with discoloured margins are visible on florets that contain larvae, and in the majority of cases these apertures are about one-third the length of the floret from the top. Usually each infected floret contains only one larva, but occasionally two larvae may be found, and in one example I found four larvae within a single floret. I have never observed more than a single fully-grown larva in the completed larval chamber; it is therefore probable that where more than one young larva enter a floret all except one eat their way out again and enter other florets. On reaching the base of the corolla tube the young larva bores into the developing ovule and by its activities in this position induces the formation of the gall.

The recently hatched larva measures about $0{\cdot}5 \times 0{\cdot}1$ mm. and has a glistening white appearance; it is cylindrical in shape and slightly thicker at the anterior than at the posterior end. There are two pairs of very small papillae on the anterior segment placed just above the mouth hooks; the lower pair, nearest the mouth, are the sense-organs or palpi, and the upper pair are the antennae (Mik). The pharyngeal skeleton is well developed and very similar in shape to that of the fully grown larva, with the obvious difference that it is very slender and slightly chitinised. At the posterior end of the body the spiracles are visible under a high magnification, as two light-brown spots, and each spiracle possesses three apertures.

The larvae do not grow very rapidly at first; two larvae fourteen days after hatching measured only $0{\cdot}6 \times 0{\cdot}12$ mm., and a larva five weeks old measured $1{\cdot}3 \times 0{\cdot}4$ mm. During the following two or three weeks growth is very rapid; two larvae that were about eight weeks old (Aug. 13th) measured $3{\cdot}5 \times 1{\cdot}5$ mm., and $3 \times 1{\cdot}8$ mm. respectively. The posterior surface of the last segment in both these larvae was becoming dark in colour and strongly chitinised; in larvae preserved early in September these characters are fully developed, and in addition

the area round the mouth is changing to a reddish-brown colour, and undergoing chitinisation. A series of fine grooves which radiate in a backward direction from the mouth are very apparent about this stage. These grooves or striations are present on younger larvae (Aug. 22nd) but in order to see them it is necessary to strip off the cuticle from the anterior part of the body and examine it under the microscope; this area is not chitinised in larvae at this stage; in those larvae, however, where this area has become chitinised the grooves can be much more easily seen. A series of small channels at the sides of the oral lobes in the larva of *Musca domestica* L. is described and figured by Hewitt (1908). The grooves referred to above may correspond to those of the house-fly larva.

The first appearance of the chitinised area round the mouth aperture probably coincides with the nearly completed feeding period. From mid-September to early October the majority of the larvae are fully fed, and they remain head downwards in the larval chambers until pupation commences in the following spring; the larvae reverse their position just before pupation. During the period of feeding, and the growth of the gall, an opening of the larval chamber to the exterior is maintained, and this opening is sufficiently wide to allow the imago to emerge; this opening is situated at the apex of the chamber and is much narrower than the basal part in which the larva hibernates.

The fact that the larva remains head downwards with the strongly chitinised posterior segment uppermost and stretched across the larval chamber where it fits very tightly, suggests the explanation that this is a contrivance for avoiding or preventing the attacks of parasites or other predaceous enemies during the prolonged hibernating period. This suggestion is made by Connold and is, I think, a very probable one. He, however, states that pupation takes place in October. Of course, this may be so in the South of England, although I doubt it.

The larvae of *U. cardui* remain head downwards during the winter (Mik), and Goureau notes that the larvae of *U. cuspidata* also remain in this position until pupation commences. In Dufour's account of the life-history of *U. quadrifasciata* there is no mention of this peculiarity; it may be inferred, however, that the larvae of this species hibernate in a similar manner to those described.

I have never been able to convince myself that frass is present in the larval chambers. In the galls of *Cirsium arvense* caused by larvae of *U. cardui*, Mik found in the upper portions of the larval chambers "Excrementen in der Form von lichtbraunen Krümchen"; possibly

the larvae of *U. solstitialis* derive the greater portion of their food from the sap liberated by rupture of the cells which line the larval chamber. If this assumption is correct, then the absence of frass might be explained, as in this case practically all the food would be absorbed.

The evidence obtained leads to the conclusion that there is only one brood produced each year. Early in September, 1912, I obtained young larvae from flower-heads gathered at Prestatyn and then thought that possibly two broods were produced in one season; as I have never found pupae or empty puparia during the months of August, September, and October, the conclusion arrived at is that the young larvae obtained in September, were the progeny of late-emerged flies and that there is only one brood produced each year in this part of the country. Goureau states that in France *U. cuspidata* gives rise to two broods in favourable seasons.

The life-history of *Urophora solstitialis* may be briefly summarised as follows:

Egg stage. 8–12 days, from end of June, during July and early August.

Larval stages. Feeding period three months or less; from early July to early October.

Hibernating stage of larva. About seven to seven and a half months, from early October to mid-May.

Pupal stage. About 4–5 weeks. From mid-May to end of June.

Imago. Length of life uncertain, probably at least a month. (I have kept them alive for three weeks.) They emerge from mid-June to end of July and early August.

There is a certain amount of overlapping in the times given above owing to the extended period of emergence of the imagines.

Description of the mature larva.

There is considerable variation in the size of the fully fed larvae; thus, three examples taken from one gall in November measured 2·8 × 1·5; 3·5 × 1·7; 4 × 2 mm. respectively; the average size of five large larvae was 4·4 × 2 mm.

Naturally the variation in size is also exhibited by the pupae as will be seen from the measurements of these given further on. A probable explanation of this variation is that the smaller individuals develop from eggs laid by late-emerged flies and consequently the feeding period is much shorter than in the case of those which develop from eggs laid

earlier in the season ; it is also possible that where several larvae, say eight to ten are feeding together in one flower-head, there is not sufficient nourishment to enable them all to reach a large size.

The larvae are ellipsoidal in shape ; the anterior end is bluntly pointed and the posterior end sharply truncate, and the greatest width is across the anterior third of the body (Fig. 9). With the exception of a very few extremely small hairs on the posterior surface of the last segment, the body of the larva is completely smooth and free from bristles or spines ; Bezzi (1913) in his very useful account of the Trypaneidae states that " the under surface [of Trypaneid larvae] bears transverse rows of small black spines directed backwards," and further, that " the anal end is somewhat impressed, contoured by a variable number of fleshy points or tubercles, some of which bear also chitinous spines." Neither of these characters is present in the fully grown larvae of this species, nor according to Mik in those of *U. cardui* ; in his description of the larvae of this species he says they showed " keine Spur von Dornchen " and " die Larve ist also völlig kahl, glatt " ; as far as can be judged from the descriptions of the larvae of *U. cuspidata* and *U. quadrifasciata* given by Goureau and Dufour, the larvae of these species possess neither spines nor anal tubercles. The larvae of these four species differ therefore from the majority of Trypaneid larvae in these two features, which, according to Bezzi, are possessed by Trypaneid larvae in general.

In colour the fully grown larva is pale creamy white, except at the ends ; the two anterior segments are reddish brown, and the posterior segment is pale yellow round its anterior border, merging into a very dark chestnut-brown, almost black, colour on its posterior surface ; the two areas surrounding the spiracles are lighter in colour.

The segmentation of the larva is well defined except at the anterior end ; Bezzi states that the number of segments in Trypaneid larvae generally is usually fourteen. I have been able to distinguish only thirteen segments in these larvae, and Goureau regarded the larvae of *U. cuspidata* as probably possessing twelve segments, excluding the head ; there may be a fusion of two segments in the cephalic region of these *Urophora* larvae. On the ventral surface of the middle segments there are indications of creeping-pads (Kriechschwielen).

The mouth appears as a slit whose long axis is dorso-ventral ; the antennae and sense-organs are difficult to make out on fully grown larvae, in fact I have never been able to make them out satisfactorily ; probably they are retracted into the body together with the cephalo-

pharyngeal apparatus when chitinisation of the oral segment takes place. They can be observed on larvae about 7–8 weeks old, but they are very minute, measuring about 12μ in length and 8μ in diameter; in larvae of this age there can be seen in addition, a number of small papillae bordering the dorsal and dorso-lateral lobes of the mouth. The fine radiating grooves which surround the mouth have already been referred to.

The complete cephalo-pharyngeal skeleton consists of three pairs of sclerites and an unpaired V-shaped sclerite. The mandibular sclerites or "great hooks" each possess a prominent anterior tooth, a smaller median tooth, and a basal tooth or spur, and each sclerite is perforated near the base by a small aperture; Hewitt (1907) described a similar perforation in the corresponding sclerites of the larva of *Anthomyia radicum* L. The mandibular sclerite articulates with the intermediate or hypostomal sclerite, which in *U. solstitialis* appears to be fused with the posterior or cephalo-pharyngeal sclerite; in this latter sclerite there is a deep indentation posteriorly between its dorsal and ventral prolongations, and these again are frequently bifurcated. With careful observation a membrane can be observed surrounding each prolongation extending some distance behind them; a corresponding membrane is figured by Mik in *U. cardui*.

A V-shaped sclerite is situated beneath the hypostomal sclerites; each free end of the V articulates with a ventral projection of the hypostomal sclerite on each side, and the apex of the V is placed near the bases of the two mandibular sclerites (Fig. 8). It may be called the sub-hypostomal sclerite. The examination of a number of preparations of the cephalo-pharyngeal apparatus reveals numerous slight variations in size, shape, and amount of chitinisation of these structures; these variations are more especially noticeable in the posterior sclerite. Interposed between the mouth and the mandibular sclerites there is found another strongly chitinised body; this only becomes apparent towards the close of the feeding period, and probably consists of the closely apposed and chitinised sides of the oral lobes.

In appearance and structure, the anterior and posterior spiracles are very similar to those of *U. cardui* figured and described by Mik; he described the anterior pair as being situated on the second segment (of the pupa). In *U. solstitialis* the anterior pair are placed dorso-laterally on the third apparent segment, and near its posterior border, about 0·3 mm. apart (Fig. 11). They are yellowish-brown in colour and do not project above the surface of the body; each spiracle consists

of three short papillae joined together at the base ; a slightly elliptical aperture is situated at the apex of each papilla, and these lead into the spongy felted-chamber (Filzkammer) which is in communication with the longitudinal canal. In some preparations I have been able to distinguish a membrane between the inner boundary of the felted-chamber and the longitudinal tracheal canal, and this is perforated by a small aperture 4μ in diameter (Fig. 15).

The posterior segment bears the anus and the posterior spiracles ; it is wider on the ventral aspect, where the anus is situated in the mid-ventral line, than on the dorsal and lateral aspects. A shallow horse-shoe shaped depression is present on the posterior surface of this segment at a short distance from its dorsal and lateral borders, and a slight depression, situated just dorso-median to the posterior spiracles, is also apparent. The surface is marked with a number of very fine grooves or lines which run in various directions ; round the spiracles they are arranged concentrically. A number of small darker-coloured areas may be observed on various parts of this surface, particularly on the ventral portion ; they indicate the points of attachment of muscles (Fig. 12).

The posterior spiracles are situated slightly nearer the dorsal than the ventral aspect, as in the larva of *U. cardui*, and they are about 0·7 mm. apart. They are larger than the anterior spiracles and darker in colour ; anatomically they are very similar to these but the apertures are more definitely elliptical in shape and are arranged in a radiate manner. They project very slightly from the body surface (Fig. 14). In one instance a variation in the number of apertures in the left posterior spiracle of a larva was noticed ; this spiracle possessed four apertures instead of the usual number three.

In concluding this description of the larva, the small number of lobes or papillae of the anterior spiracles as compared with the number on the anterior spiracles of many other Trypaneid larvae may be noted ; Banks (1912) describes nine Trypetid (Trypaneid) larvae whose anterior spiracles each bear a large number of lobes varying from about fifteen in *Ceratitis capitata* Wied. and *Rhagoletis pomonella* Walsh, to thirty-eight lobes in *Dacus ferrugineus* Fab. ; whereas in the larva of *U. solstitialis* and *U. cardui* (Mik) three lobes only are borne on each anterior spiracle.

Description of the pupa.

The pupae vary considerably in size as may be expected from the great variation in size exhibited by the larvae; among ten selected for measurement the largest measured 4·3 × 2 mm. and the smallest 2·8 × 1·4 mm., the average size of the ten pupae was 3·6 × 1·7 mm. In shape they are cylindrical, obtuse or bluntly pointed at the anterior end, and obliquely truncate dorso-ventrally at the posterior end; during pupation there is little or no alteration in length but the pupa is more parallel-sided than the larva (Fig. 10).

The colour varies from light yellow to dark reddish-brown; the majority, however, are of the lighter colour, and in all specimens the first three or four segments and the last one are much darker in colour than the intermediate ones. These anterior and posterior segments vary in colour from reddish-brown to dark chestnut-brown or black. On the surface of the puparium a number of anastomosing wrinkles are seen which vary in direction in different parts of the same; they are more or less parallel to the segmental grooves on the dorsal and ventral aspects of the middle-segments, but at the sides they run obliquely. These wrinkles are darker in colour than the smooth portions of the puparium, and represent wrinkles of the larval skin which become more apparent through shrinkage undergone during pupation.

At the anterior end the radiating grooves which run in a backward direction from the mouth are very noticeable, and the anterior spiracles are visible under a good lens as two brown spots in the position described in the larva.

The posterior aspect exhibits the same features as in the larva and requires no further description; there is a variable amount of wrinkling around the margin of the last segment, but well-marked ridges similar to those figured by Mik on the posterior surface of the pupa of *U. cardui* are not apparent. The pupae have a dull glistening appearance; Mik described the appearance of the pupa of *U. cardui* as "etwas seidenglänzend."

Connold's figure of the pupa of *U. solstitialis* is incorrect; the object figured resembles a syrphid larva.

Effects of larvae on production of seeds in galled flower-heads of Centaurea nigra *L.*

In order to obtain some definite information concerning the effects of the *Urophora* larvae on the production of seeds, a number of plants were collected and a series of counts made. Perfect accuracy is not claimed for the results obtained, as, owing to various circumstances, the conditions were such that a high degree of accuracy could not be expected. The plants were collected on Oct. 1st, 1913, that is to say, late in the season, when many of the seeds had certainly escaped, in addition to those probably taken by seed-eating birds. As the plants, however, were collected within a space of about twenty square yards, it may be assumed that these factors affected all the plants in this area in a more or less similar manner. Fifty plants, single shoots cut off at the ground-level, were selected, and these bore 147 flower-heads; twenty-four of these, however, were immature and therefore disregarded. Of the remaining 123 heads, seventy-four or 60·1 per cent. contained galls, whilst forty-nine or 39·8 per cent. were ungalled. Nine of the galled heads contained no seeds, and these for the purpose of calculation were neglected; from the remaining sixty-five galled heads 1077 seeds were obtained, averaging 16·5 seeds per head.

Twenty-five of the forty-nine ungalled heads were rejected for various reasons; ten contained no seeds whatever, whilst the seeds in the remaining fifteen were more or less eaten by seed-eating lepidopterous and free living dipterous larvae.

From the twenty-four ungalled heads that were considered countable, 755 seeds were obtained, averaging 31·4 seeds per head. Thus showing a reduction of nearly 50 per cent. (31·4 – 16·5) in the number of seeds produced in the galled heads, compared with the number produced in ungalled heads. The number of seeds (31·4) per head obtained from these particular heads is very low, and would be misleading if one were to assume that this was the average number obtainable from normal well-grown flower-heads of *Centaurea nigra*.

It may be explained that the soil on which the above plants were grown was very poor and stony, and the specimens were gathered late in the season when some of the seeds had escaped, as stated above; these considerations may help to explain the small average number of seeds per head.

By way of contrast may be quoted the number of seeds obtained from some flower-heads of the knapweed gathered by Prof. Hickson,

near St Bees, Cumberland, early in September of the same year. These results give a more accurate idea of the number of seeds present in well-developed flower-heads of this weed.

From twenty-seven flower-heads 2045 seeds were obtained; averaging 75·7 seeds per head; one flower-head contained 103 seeds, whilst the smallest number found in one head was sixty-two. A collection of flower-heads was also made at Port Erin, Isle of Man, early in September, and one head yielded the very high number of 109 seeds.

These figures indicate the large number of seeds that may be ripened in a fully-developed flower-head of this plant, and it may be of some interest to make an estimate of the number of seeds that a single plant of this species is capable of producing.

Several plants of the knapweed were grown for experimental purposes last summer, in my garden at Northenden, in Cheshire, and one of them gave rise to several particularly lusty shoots; one of these bore fifty-one flower-heads, and if it is assumed that each head ripened only thirty-one seeds (the average number obtained from heads gathered at Prestatyn) we obtain the number 1581 seeds producible on one single shoot. A vigorous plant growing in good soil would give rise to at least three or four shoots, so that several thousands of seeds may be produced on one plant. Long (1910, p. 175) remarks that "knapweed (*Centaurea nigra* L.) known under a variety of names as Hardheads, Hardhack, Blackhead, is a too common weed of pastures and meadows," and in view of the above estimate of its seed productivity, this is not surprising. Were it not for the fact that several insect larvae and birds feed on its seeds it would be even still more abundant.

A germination experiment was also made to test the difference, if any, between the seeds ripened in galled heads and those in ungalled heads, with regard to their vitality or germinative power.

A large number of seeds from the ungalled flower-heads collected in October were taken and mixed together; after rejecting all seeds that showed evidence of injury, *i.e.* indications of having been partially eaten by other insect larvae, 100 seeds were separated without exercising any selection. These were placed on moist blotting paper in a seed-germinating apparatus, and kept at a temperature of 26° C. From these seeds eighty-nine seedlings were obtained, equivalent to 89 per cent.

In a similar manner 200 seeds were selected from the galled flower-heads that were collected on the same date and these were placed in the germinating apparatus at the same time. That is to say, both lots of seed were collected at the same time and place, and germinated under

similar conditions. Of these seeds only fifty-seven germinated, equivalent to 28·5 per cent.

The percentage of germination in the seeds tested from galled flower-heads was thus reduced 60·5 per cent. owing to the presence of *Urophora* larvae in the receptacles of the flower-heads ; probably the nourishment that normally goes to the developing seeds, becomes diverted to the growing larvae and also to the formation of the thick-walled woody gall.

This experimental result coincides with the indications given by the appearance of the seeds usually obtained from galled flower-heads ; many of these seeds are shrivelled, and smaller than the majority of those collected from ungalled heads.

Thus in addition to a reduction in the number of seeds produced in the galled flower-heads, the number of seeds capable of germination is also reduced. Taking into consideration the smaller number of seeds obtained from infected flower-heads, and also the reduced vitality of those actually ripened, as indicated by the above experiments, it may be stated that the presence of the larvae of *Urophora solstitialis* in the flower-heads of *Centaurea nigra* reduces the number of effective seeds in these infected heads at least fifty per cent.

Although the Trypaneidae or fruit-flies are justly regarded as injurious from the economic standpoint because many of them are very destructive to various cultivated fruits and to vegetable life in general, yet those species whose larvae feed on, or in, the stems, leaves, flower-heads and seeds of the weeds of cultivated land, may be regarded, from the agricultural point of view, as beneficial. The result of the activities of their larvae is that the plants fed upon are affected adversely, and in many cases, as in the case of the species considered in this paper, the production of seeds is directly checked ; the distribution of the weeds attacked is therefore restricted, even if only to a moderate extent.

The question occurs as to whether destructive weeds could be appreciably reduced by encouraging certain species of insects which attack the seeds thereof. It is hoped that the present paper will suggest to others the possibilities for further research and experiment in this field of enquiry, which is fully worthy of attention from the economic entomologist.

Parasites.

Three species of Chalcids and one Braconid emerged from the flower-heads in May 1912 and 1913, but in very small numbers; presumably some of these were parasitic in the *Urophora* larvae. The Chalcids have not as yet been identified; Mr Claude Morley, however, has kindly named the Braconid, it is *Bracon minutator* Fab., and probably parasitic on the lepidopteron *Parasia metzneriella* Stt. Brischke (1882) records this parasite from the larvae of *Sesia* (*Bembecia*) *hylaeiformis* Lasp. (not a British species); Marshall (1885) states that Elisha bred two females of this Braconid from the lepidopteron *Argyrolepia zephyrana* Tr. It therefore appears probable that *Bracon minutator* is parasitic on lepidopterous hosts. Under the description of *Bracon variator* Nels., Marshall says "It is doubtful whether this *Bracon* is a parasite of certain small curculios (*Cionidae*) or of flies of the genus *Trypeta*" and further on he states that "Giraud records *B. nigripedator* Nees, from *Urophora solstitialis* L.; and Fitch once obtained a Bracon, now lost, from galls of *Centaurea* inhabited by the same fly."

With regard to these records of parasitic hymenoptera obtained from flower-heads of *C. nigra* and other composite plants, I would remark that unless it is proved that dipterous larvae and pupae alone are present therein, it is incorrect to state definitely that they are the hosts of the parasites obtained, inasmuch as a single flower-head may contain the larva or pupa of a lepidopteron in addition to those of diptera.

Kaltenbach states that *Eurytoma aterrima* Schr. (*verticillata*) is parasitic on *U. solstitialis*, and probably also *Trigonoderus amabilis* Walk. and *Semiotellus* (*Semiotus*) *diversus* Walk. Walker (1833–37) records these three Chalcids from near London but does not give their hosts.

Mr C. Morley (1908), from a quantity of dried heads of *Centaurea nigra* gathered in March, 1907, beneath fir-trees, obtained both sexes of a *Pteromalus* in May, and numerous *Bracon minutator* ♂ in April; he also obtained one specimen of *Pimpla sagax* Htg. on April 26th, and of this specimen he says (p. 81) "Its host was undoubtedly *Urophora solstitialis*, many of which emerged during the following June; unless, of course, its presence there were purely accidental and its true association were with the overhanging conifers, in which case it would surely have shown itself in the jar in the course of the preceding month." In view of the fact that with one exception, viz. *Anthonomus pomorum* L. all the recorded hosts of this ichneumon are lepidopterous, and as the

larvae of at least three species of lepidoptera have been recorded from *Centaurea nigra*, the evidence adduced by Mr Morley that *U. solstitialis* is a host of *Pimpla sagax* is hardly conclusive. It seems more probable that the single specimen obtained by him either emerged from a lepidopterous host, or that its presence in the flower-heads was accidental, as he indeed suggests.

Five hymenopterous larvae, probably of a Chalcid, were obtained from 259 larval chambers examined in October, 1913, equivalent to two per cent. Each of these larvae occupied a chamber that had previously contained a *Urophora* larva. In one case there was direct evidence that the hymenopteron had fed on the dipterous larva, as the parasitic larva was inside a portion of the cuticle of the *Urophora* larva and had evidently been feeding on the latter. From material in hand I hope to be able to breed out a further supply of these Chalcids, to get them identified, and to obtain the percentages.

Remarks on Gall-formation and on other inhabitants of the flower-heads of Centaurea nigra.

The process of gall-formation in the flower-head of the host plant exhibits some very interesting features. To determine whether the formation of this gall is induced mechanically by the feeding habits of the larva, or whether the latter secretes an irritant fluid which causes the abnormal growth, would require further observations. The tissues of the receptacle near the ovule attacked commence to swell up shortly after the larva begins to feed, and in a comparatively short time the size and shape of the future hibernating chamber of the larva are marked out in the gall, although the larva is far from its full size. In a longitudinal section of a gall that contained a larva about four weeks old and 1·3 mm. in length, the outline of the future hard-walled chamber could be clearly distinguished. A thin layer of woody tissue is developed within the hypertrophied tissue that the larva is feeding on, and a thick layer of soft nutritive tissues is left within this woody layer and the space occupied by the larva (Fig. 5); this nutritive layer is connected at the base of the chamber with the vascular system of the plant.

During the period that elapses between this stage and the attainment of the fully fed one, the larva gradually eats away this layer of soft tissue, until finally when the growth of the larva is complete the layer of soft tissue has been absorbed and the hard wall of the chamber reached (Fig. 6); meanwhile the wall becomes more lignified and

harder, and the tissue between adjacent chambers that have fused together also becomes drier and harder, and in this manner the hard plurilocular gall is produced (Figs. 3 *a* and 4).

The interesting fact revealed during this process is that the stimulus produced by the presence of the larva in the embryonic tissue of the developing ovule, and in the hypertrophied receptacle, induces a reaction of the plant to form a structure that is possibly protective to the plant itself, but which is also at the same time exactly suited to the requirements of the fully-grown larva, forming as it does a very efficient means of protection to the larva during the prolonged period of hibernation.

Several larvae, pupae, and imagines of *Parasia metzneriella* Stt. were obtained from the flower-heads during this investigation; 30 % of the heads examined were found to contain these lepidopterous larvae. By far the greater number of larvae were found in chambers that had originally been made by *Urophora* larvae, and it is a subject for further investigation to find out what becomes of the original occupants of these chambers.

Eleven larvae of an unidentified dipteron were found feeding on the ripening seeds; they were found in 9 per cent. of the heads examined. Small orange-coloured larvae of a Cecidomyid were very abundant, almost every flower-head examined contained several specimens.

A lepidopterous larva which differed from that of *P. metzneriella* was found feeding on the seeds in 25 per cent. of the flower-heads collected by Prof. Hickson at St Bees; as the moth has not yet emerged, I have not been able to identify the species to which it belongs.

The larvae of two species of *Coleophora, C. alcyonipennella* Koll. and *C. conspicuella* Z. are recorded from *Centaurea nigra*. The larvae found at St Bees may belong to one of these two species.

SUMMARY.

1. A description of *Urophora solstitialis* L. and an account of its systematic position and geographical distribution are given, together with an abstract of the work of previous observers on this species.

2. A list of its British and continental food-plants is given; the records of the latter show that on the continent the larvae feed on various species of thistles, and on three species of *Centaurea*, but not on *Centaurea nigra*, whereas with the exception of one record of their occurrence on *Serratula tinctoria*, the larvae in this country are recorded as feeding exclusively on *Centaurea nigra*.

3. The life-history, ovipositor, and method of oviposition are described, and descriptions and figures of the ova, larvae, and pupae are given. The life-history is summarised on p. 148.

4. It is shown that owing to the formation of galls induced by larvae of *U. solstitialis* in the flower-heads of this weed a reduction in the number of seeds is effected amounting to about 50 per cent. in the heads examined. The germinative capacity of the seeds produced in these galled heads was also adversely affected. In the germination experiment described 60·5 per cent. fewer seeds germinated from galled flower-heads of *C. nigra* than from ungalled ones. At a moderate estimate the number of seeds rendered non-effective in galled flower-heads of *C. nigra* is placed at 50 per cent. It is pointed out that Trypaneids, whose larvae adversely affect the weeds of cultivated land, may be regarded as beneficial.

5. A short account and discussion of the recorded parasites of *U. solstitialis* is given.

6. Some interesting features observed in the process of gall-formation are referred to, and a few notes are added on some other insect inhabitants of the flower-heads of *C. nigra*.

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Summary of results obtained from the examination of 50 *shoots of* Centaurea nigra *gathered Oct.* 1*st*, 1913, *at Prestatyn, North Wales.*

45 of the 50 shoots carried galled flower-heads, *i.e.* 90 % were infected.	No. of heads obtained from 50 shoots, 147; average, 3 per shoot. 24 were immature; of the remaining 123, 74 (60·1 %) contained galls and 49 (39·8 %) were ungalled.	No. of heads	No. of larval chambers per head	Total No. of larval chambers, 259; average, 3·5 per head	No. of seeds obtained from 65 galled heads, 1077; average 16·5 seeds per head.
		1	11		
		1	10		
		1	9		
		2	8	Total No. of larvae obtained, 170	No. of seeds obtained from 24 ungalled heads, 755; average, 31·4 seeds per head.
		3	7		
		5	6		
		6	5		
		13	4		
		14	3	No. of chambers found either empty or containing hymenopterous or lepidopterous larvae, 89.	200 seeds from galled heads on germination yielded 57 seedlings (28·5 %).
		10	2		
		18	1		
		74	Total 66		100 seeds from ungalled heads yielded 89 seedlings (89 %).

Remarks. The greatest number of larval chambers found in a single flower-head of the above fifty examined was eleven, and this number occurred only once; eighteen heads contained only one larval chamber each. The greatest number of chambers found in one head during the investigation was thirteen.

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EXPLANATION OF PLATES.

PLATE XI.

Fig. 1. *Urophora solstitialis.* Female, ×5; ovipositor partially extended.

Fig. 2. Vertical section through young flower bud of *Centaurea nigra*, showing eggs *Ov.* of *U. solstitialis in situ.* 24 hours after oviposition. ×9.

Fig. 3. A. Ungalled receptacle of *C. nigra.* × 2.
B. Galled " " " "

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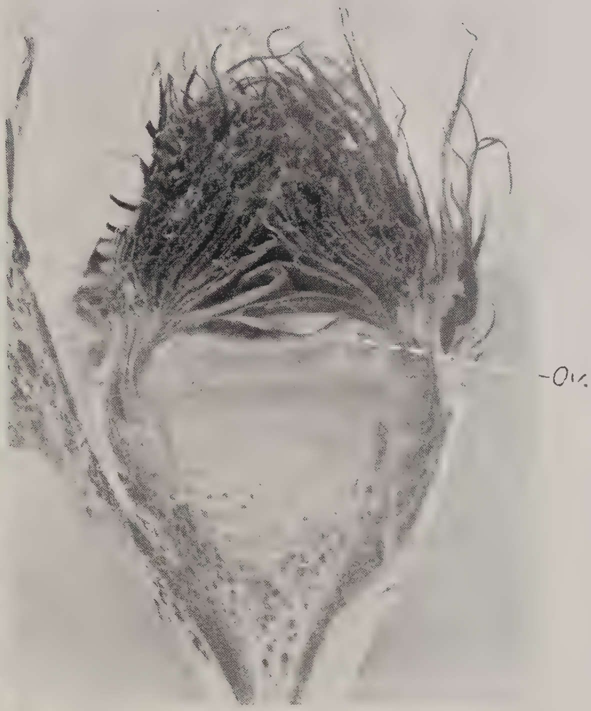

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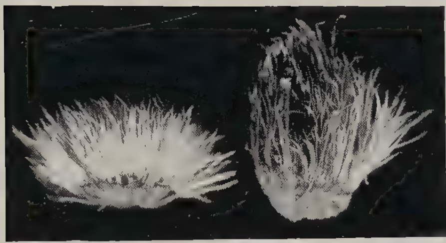

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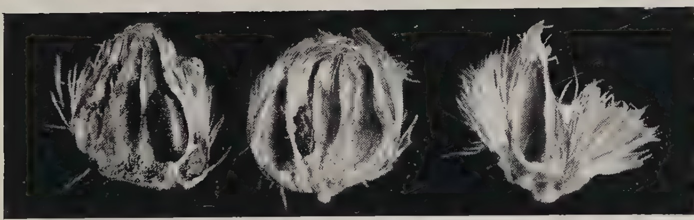

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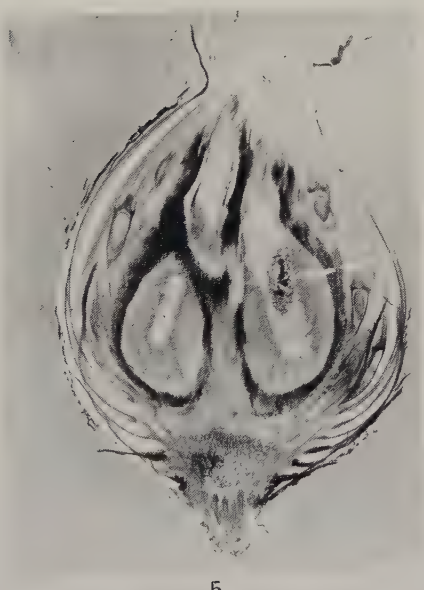

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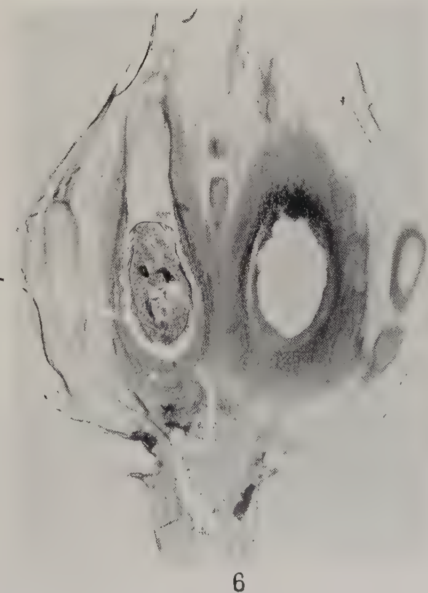

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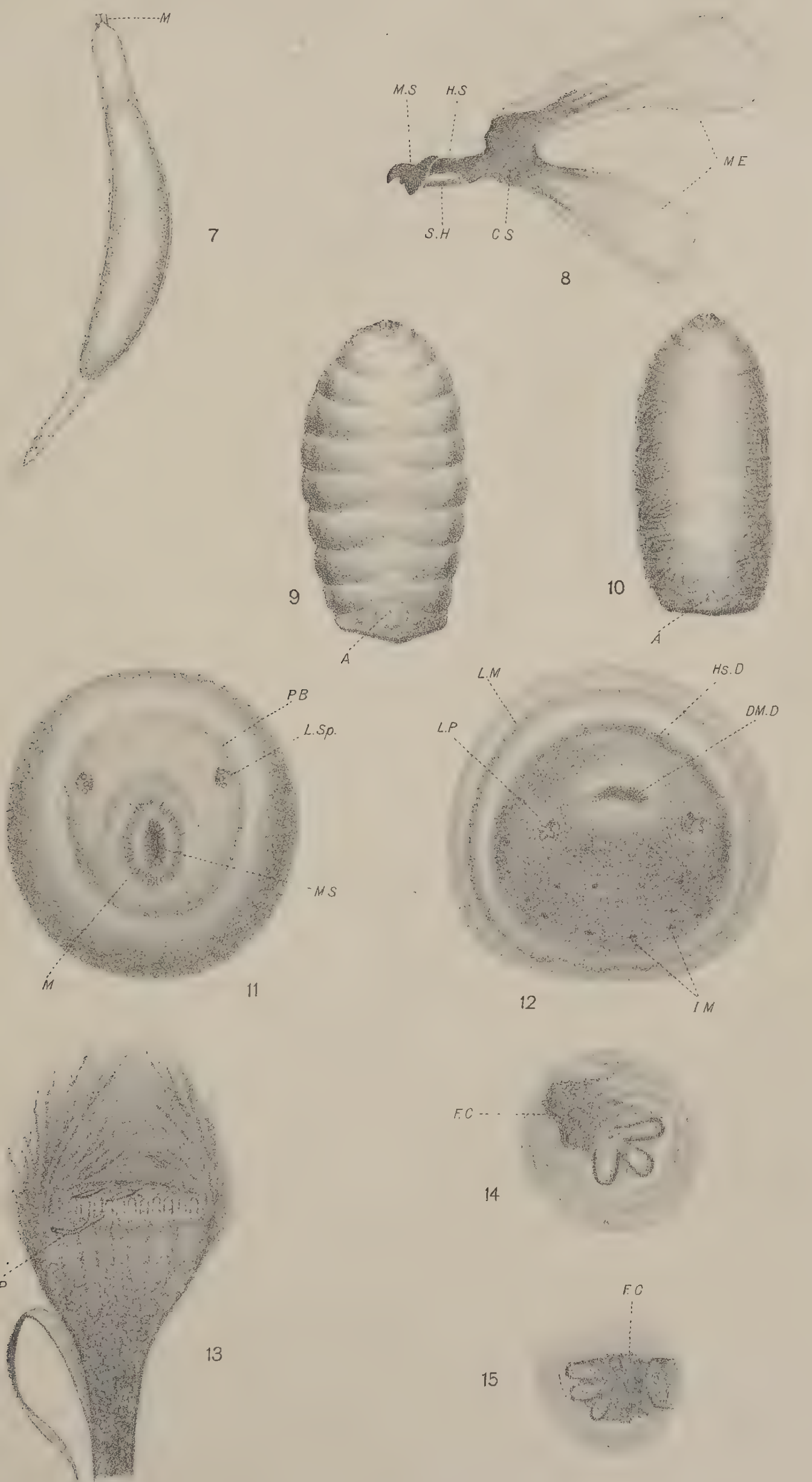
Urophora solstitialis.



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UROPHORA SOLSTITIALIS.

Fig. 4. Vertical section through three galled flower-heads of *C. nigra* showing the chambers in which the larvae hibernate during winter, and where pupation takes place. The left hand one contains a pupa. ×2.

Fig. 5. Vertical section through a galled flower-head of *C. nigra*; the section shows the hard woody walls of two chambers; the right chamber contains a section of a larva and shows the thick layer of nutritive tissue that is separated from the remainder of the receptacle when the woody layer is developed. The section is slightly tangential, and the larva is younger than the one in Fig 6. ×5. *l.* section of larva.

Fig. 6. Section similar to Fig. 5 containing an older larva in the left chamber, the nutritive layer has been almost eaten away by the larva, and the woody wall reached. ×5. *l.* section of larva.

PLATE XII.

Fig. 7. Egg of *U. solstitialis.* 24 hours after oviposition. ×50; *m.* micropyle.

Fig. 8. Cephalo-pharyngeal skeleton of mature larva from the left side. ×120. *m.s.* mandibular sclerite; *h.s.* hypostomal sclerite; *c.s.* cephalo-pharyngeal sclerite with deep indentation between dorsal and ventral processes which exhibit further bifurcations; *s.h.* sub-hypostomal sclerite; *m.c.* membrane surrounding each process of the cephalo-pharyngeal sclerite.

Fig. 9. Mature larva, ventral aspect. ×10. The larva was slightly lifted upwards anteriorly bringing into view the mouth-slit and the anterior spiracles. *a.* anus.

Fig. 10. Puparium, ventral aspect. ×10. *a.* anal scar.

Fig. 11. Anterior view of mature larva. ×45. *p.b.* posterior border of third segment. *l.sp.* left anterior spiracle. *m.s.* mouth-slit with the dark chitinised sides of the oral-lobes. *m.* posterior margin of the chitinised area surrounding the mouth.

Fig. 12. Posterior view of last segment of mature larva. ×50. *l.m.* lateral margin of last segment *hs.d.* horse-shoe shaped depression. *dm.d.* dorso-median depression. *l.p.* left posterior spiracle. *i.m.* indications of muscle-attachments which appear as dark areas on the surface.

Fig. 13. Vertical section of flower-bud of *C. nigra* showing the passage *p.* made by ovipositor during the process of oviposition. ×5. The ovipositor had passed on both sides of the third floret from the left-hand side, as indicated in the drawing.

Fig. 14. Right posterior spiracle of mature larva viewed from above. ×200. *f.c.* felted-chamber (Filzkammer).

Fig. 15. Left anterior spiracle of nearly mature larva viewed from above. ×200. *f.c.* as Fig. 14.

NOTE. In figs. 14 and 15 the felted-chamber (*f.c.*) is displaced laterally. In the larva the chamber is directly beneath the spiracular openings.

Figs. 7, 8, 11, 12, 14, and 15 were drawn by the aid of the Zeiss-Greil drawing apparatus.

A BRACONID PARASITE ON THE PINE WEEVIL, *HYLOBIUS ABIETIS.*

By J. W. MUNRO, B.Sc. (Agr.), B.Sc. (Arb.), Edin.

The following notes are the result of observations made on pine weevils and parasites collected in a plantation on the estate of Banchory Devenick near Aberdeen. The plantation in question was formed in the spring of 1911, a year after the removal of the old crop which was a pure wood of Scots pine. The stumps and roots of this old wood afford ideal breeding places for the pine beetle (*H. piniperda*) and the pine weevil (*Hylobius abietis*), and they are to be found in considerable numbers.

Fig. 1. Larvae of *H. abietis*. ×6.

The work of the pine weevil is familiar to all interested in forestry. It is harmful only in the adult state and does considerable damage by gnawing the tender bark of young conifers causing them to wilt and die. Where conifers are not to be got it will readily attack birch, mountain ash, and oak.

In the larval stage *Hylobius* is harmless. The adult deposits her eggs in or under the bark of the stumps of various conifers but prefers Scots pine. The larva on hatching out, commences to tunnel between the bark and the sapwood, and when full grown pupates at the end of this tunnel, either in a cavity or hook gallery in the sapwood, or in a cavity in the bark. The tunnels are filled with frass, consisting of tiny chips of wood bitten out by the larva and passed through its body.

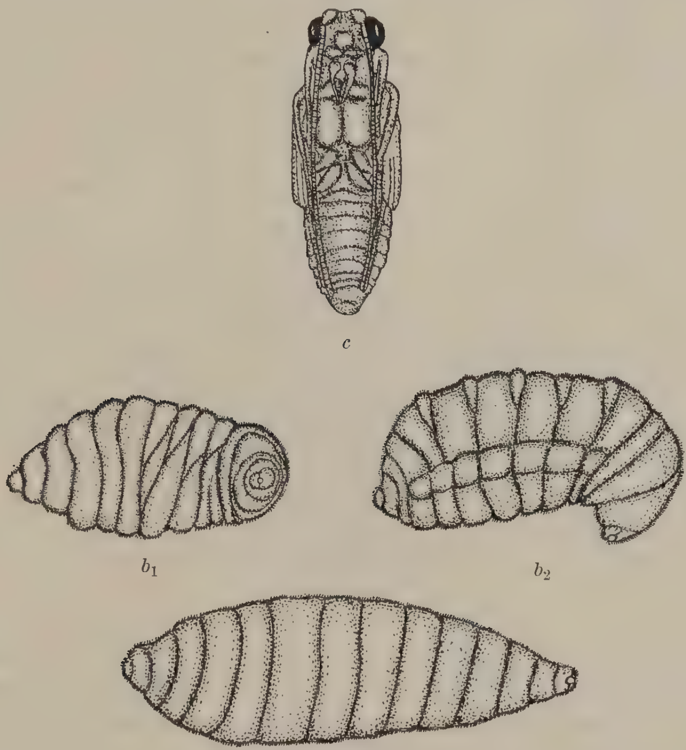

Fig. 2.

a, b. Larvae of *B. hylobii.* $\times 12$. (*a* after first moult. *b* after second moult.)
c. Pupa of *B. hylobii.* $\times 12$.

The whole of the larval life is passed in such a tunnel. In the spring of 1912 I noticed a few tiny cocoons lying in one of these tunnels but I attached no importance to them at the time. In July of last year, however, I found several weevil larvae apparently in the resting stage, which were attached by a small legless maggot feeding externally on

them. I collected a number of weevil larvae both attacked and immune, and also a number of the attacking maggot. In some cases the weevil larvae were sucked quite flat and in a few days all those which had been attacked were in this condition. Accordingly I supplied the parasitic larva with more grubs and found that they readily fed on them, crawling two or three inches to reach their new prey.

These parasitic larvae measured somewhat over ¼ inch in length, and were covered with very short reddish brown hairs. Unfortunately I was unable through lack of proper instruments to make a close examination of them and I could not make out the mouth parts. Observation showed, however, that they fed through the skin of their host and were purely external parasites. In September the parasites ceased feeding, and a few days after they moulted and became more definite in shape, and I assumed then that they were Hymenopterous. A fortnight later, on September 25th, they commenced spinning silky cocoons and in a few hours they were completely hidden. All through the winter I examined a few of these cocoons every week, but no alteration in the external appearance of the enclosed larvae was visible until February 20th, when in two out of five cocoons I found pupae. Nine days later the first imago emerged which I recognised as a Braconid of some sort. At the date of writing, April 14th, flies are still emerging from the later gathered cocoons.

Dr MacDougall informs me that three years ago he obtained a Braconid parasite on *Hylobius*, but in such a battered condition as to be unrecognizable. So far as I have been able to ascertain I know of no other British record of a Braconid on *Hylobius*. In Ratzeburg's *Ichneumon der Forstinsekten*, however, there is a short account of the rearing by Nordlinger of 40 ♀♀ and 4 ♂♂ from the larvae of *H. abietis*. I may be permitted to quote Ratzeburg's account. "Nordlinger bred 40 ♀♀ and 4 ♂♂ from this species (*Hylobius abietis*) each of whose larvae supports about ten parasites. The cocoons of the latter are firm, oat-shaped and papyraceous, woven among their hosts frass and dead bodies, and often constructed at the end of the beetles' tunnels beneath fir bark." This description agrees in every respect with my own observations and accordingly I looked up Ratzeburg's description of the species which he calls *Bracon hylobii*. It again agrees with the insects I have bred out, and as I have been unable to identify my specimens with any of the Bracons in the South Kensington collection, or with those described by Marshall, I think it highly probable that the species I have reared are

B. hylobii. If so they are a species new to Britain, and in order to be sure of this I have sent specimens for identification to Dr Szepligeti in Budapest.

Ratzeburg's description of the species is as follows: "B. hylobii. $1\frac{1}{2}$–$2\frac{1}{2}$ mm. Outer and inner discoidal cells equally long. Second cubital cell a little larger than the first. Antennae of ♀ 31 jointed. The ovipositor as long as the abdomen and tending to curve upwards. Head approximately as broad as the thorax. All the legs and the greater part of the first half of the abdomen reddish brown. In the ♀ only the middle of the first segment is black. In the male the first

Fig. 3. *B. hylobii* ♂. ×15.

ring may be almost quite black and the last or posterior half of the abdomen in both sexes is quite black. The thorax and head black except in certain females when part of it is brownish."

Ratzeburg expresses doubt as to making it a species, but he considers that the shape and size of the discoidal cells entitle it to that distinction from its near neighbours *B. immutator* and *B. spathiformis*.

Messrs Elliott and Morley in their Hymenopterous parasites of the Colioptera refer to Ratzeburg's species but do not quote his description. These references are the only two I have been able to obtain on the subject[1].

[1] Brischke, C. G. A. Die Ichneumoniden der Provinzen West- und Ostpreussen. *Schrift. Naturfors. Gesell* Danzig Neue Folge, v, 1882, p. 135 (records the ♀ of *Bracon hylobii* but makes no comments thereon).

The degree of parasitism by *B. hylobii* on the pine weevil may be of interest. In winter 1911 I observed no cocoons. In the spring of 1912, two years after the old crop was removed and presumably in the second year of the beetles' occurrence there, I observed a few cocoons, while in 1913 and 1914 every third pupating chamber was occupied by them. This represents parasitism in the third and fourth years of the pest of over 30 per cent.

I think I do not exaggerate when I suggest that *Bracon hylobii* Ratz. may prove of considerable value in combating the pine weevil, which is every year becoming more and more common in newly formed

Fig. 4. *B. hylobii* ♀. × 15.

plantations, especially in Scotland. The parasite is, in all probability, fairly common where *Hylobius* is found. The fact that it has hitherto apparently been unrecorded does not imply that it is scarce. The persons most interested in *Hylobius*, the forester and the factor, are interested only in the adult beetle when it begins its attacks on their plantations, and any measures they may take against it are as a rule confined to the trapping and collecting of the adult. The larvae are rarely considered, and though they were disturbed and examined, the forester is neither sufficiently interested nor sufficiently educated to pay any attention to the cocoons, or larvae of a parasite, though he found them.

Parasites have already been used with success in combating other destructive insects ; notably Professor Lefroy's introduction of *Rhogas Lefroyi* into the Punjaub, to combat the boll worm, and more recently Pierce and Townsend have shown that Hymenopterous parasites play a very important part in controlling the cottonboll weevil in the States. Pierce found that of 2800 weevils, 591 were parasitised, and that of these, in 525 cases the parasite was a Braconid. In 1911 Pierce and Hunter began experiments on the rearing and distributing of the parasites but I am not aware whether a report on these has yet been published.

As to the possibility of using *B. hylobii* in combating *H. abietis*, I have not yet obtained a sufficient knowledge of the former's life-history to make any definite statement, but such observations as I have been able to make lead me to believe there are no special difficulties to overcome. If *B. hylobii* is fairly or reasonably common, and there is no reason to suppose it otherwise, there should be little difficulty in obtaining batches of its cocoons, or numbers of its larvae to breed from. The larvae of *Hylobius*, too, can readily be kept alive if they are not removed from the roots on which they are feeding. I have reared several weevils by removing the smaller roots containing their larvae and keeping these sufficiently moist. The parasite itself is easily reared inasmuch as I bred one batch in an ordinary collecting tube in which I placed a weevil grub as food.

Out of about 70 cocoons, I have obtained no hyperparasites on the Braconid. This again is favourable. The parasite too is evidently hardy. The plantation from which my specimens were obtained is a bleak hillside near the coast and over 600 feet above sea-level. It is often swept by cold North and East winds.

Another interesting fact is that *B. hylobii* attacks the weevil larva in its resting stage, at a time when the latter is practically inactive.

The greater increase in numbers of the parasite as compared with the weevil is also interesting. Every weevil grub attacked gives rise to at least five adult parasites. Of these according to Nordlinger's figures, 90 per cent. will be females, but from my own observations 60 per cent. is a more probable relation.

Assuming that every weevil grub parasitised gives rise to five adults, three of which are females, and that as in the present instance, 30 per cent. of the weevil grubs are attacked in the winter 1913–14, then out of 100 weevil grubs we should get 70 *Hylobius* adults and 90 female Braconids in spring 1914. If we assume further that the rate of increase of *Hylobius* and of *Bracon* in a given year is the same, say

ten, and that the proportion of males to females in the two insects is the same, then we should have in the winter 1914–15, 420 weevil grubs and 540 Braconid. This would, therefore, entail the complete destruction of the weevil. These figures are of course purely hypothetical. Now it is by no means improbable that the Braconid is more prolific than the weevil, and also that the proportion of females to males in the Braconid is greater than in the weevil. These, however, are points which must be cleared up before the practical value of *Bracon hylobii* as a factor in controlling *Hylobius* can be fully demonstrated.

OBSERVATIONS ON THE LIFE-HISTORY OF THE AMERICAN GOOSEBERRY-MILDEW (*SPHAERO-THECA MORS-UVAE* (SCHWEIN.) BERK.[1]

By E. S. SALMON, F.L.S.,

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The rule among the species of the *Erysiphaceae*—to which the American gooseberry-mildew belongs—is a life-cycle consisting of the production of a *conidial* stage during the growing-period of the host-plant, and the production before the advent of winter of a *perithecial* stage. In the *conidial* stage the spore is a naked, short-lived *conidium*; in the *perithecial* stage the spore is an *ascospore* which remains living for several months within the *ascus* inside the thick-walled *perithecium*.

While this is the usual life-cycle, some striking exceptions occur, particularly in cases where a species has found its way into a new continent.

When the vine-mildew (*Uncinula necator* (Schwein.) Burr.) invaded Europe, no *perithecial* stage was found associated with it for the first 47 years[2], the mildew existing during winter in the *conidial* stage in a more or less dormant condition. Appel has shown that before winter patches of hibernating mycelium are found on the stem of the vine; these produce *conidia* the next season. These hibernating patches have thicker-walled hyphae, and more numerous and larger haustoria. Although the perithecial stage of *U. necator* has been found within recent years on a few occasions in different years in France, Germany, and elsewhere, it appears that the production of *perithecia*—which are formed abundantly in America, the native home of this mildew—only takes place *exceptionally* in Europe—possibly under abnormal weather conditions.

[1] Paper read at the Meeting of the Association of Economic Biologists, on April 17, 1914.

[2] Salmon, E. S. A Monograph of the *Erysiphaceae* (*Mem. Torrey Bot. Club*, IX, 1900).

A very similar case is that of the oak mildew. About 10 years ago oak "scrub," and to some extent oak trees also, in England and in many parts of the Continent, became for the first time attacked by a species of the *Erysiphaceae* in the *conidial* stage. It received many names (*e.g. Oidium alphitoides, O. quercinum*, etc.) at the hands of mycologists belonging to that class which has sufficient time only to add to synonymy. In 1911, the discovery in France of the perithecial stage of this mildew on some autumnal shoots of the oak, proved its identity with an endemic American form of *Microsphaera alni* (Wallr.) Salm., which occurs commonly on species of *Quercus* in the United States. Here, again, quite exceptional seasonal conditions would seem to be necessary for the formation of the perithecial stage of this mildew when introduced—as presumably has been the case—into Europe from America. No perithecia have been found in this country and certainly as a general rule the oak-mildew passes the winter in the conidial stage in a more or less dormant condition.

A third case is the mildew which attacks the foliage of that very useful ornamental shrub *Euonymus japonicus*. This mildew first appeared in England, and also on the Continent, about 15 years ago, and only the *conidial* stage is known[1]. It is possible that it is a form of *Erysiphe Polygoni* endemic to Japan on *Euonymus japonicus*, and that it has been imported with that shrub from Japan into Europe. The mildew exists in Europe during the winter months on the evergreen leaves in dormant or nearly dormant hibernating mycelial patches, which on the advent of a warm spell of weather soon produce *conidia*.

What now are the facts with regard to the life-cycle of the American gooseberry-mildew (*Sphaerotheca mors-uvae* (Schwein.) Berk.) in this country, since its introduction into Europe from America about 1900? Has its normal life-cycle been interfered with in any way as the result of new factors such as change of climate or different "constitutional" characters of its host-plants? There is, I think, some reason for thinking that it has. There is no evidence that there is any hibernation of the conidial stage. The perithecial stage—or at least the outward signs of it—is formed abundantly on the surface of the young shoots of the gooseberry. It has been assumed from the first—and quite rightly so under the circumstances—that the continuance from year to year of this new and most destructive pest was everywhere ensured by this abundant production of the perithecial stage. Some facts which I have

[1] Salmon, E. S. Fungus Disease of *Euonymus japonicus* (*Journ. Roy. Hort. Soc.*, XXIX, p. 434 (1905)).

lately observed, however, show the necessity for close investigations to be made to ascertain to what extent the perithecial stage which is formed at different times during any one season remains living through the following winter and is the cause of the first spring outbreaks. The facts lately observed would seem to show that there is a real danger—if the American Gooseberry-mildew Orders are carried out by officials without the guidance of a mycologist—of fruit-growers being prosecuted and fined for not removing from gooseberry bushes *the mildew in a dead condition.*

In August last year, and during the present spring, I have observed the various details connected with the dehiscence of the ripe perithecium and the discharge of the ascospores—a process which I have not before succeeded in observing and one which, I believe, has escaped other investigators. The details will be described in the next number of the *Journal of Agricultural Science* (now in the press[1]). The dehiscence of the ripe perithecium was observed to take place in material collected last August, a few hours after the perithecia had been supplied with moisture; similar material collected in November last and kept dry in the laboratory through the winter, proved when examined in February, March, and April, to be alive, the perithecia dehiscing when supplied with moisture. The dehiscence, which occurred either almost at once—the shortest time being $1\frac{1}{2}$ hours—or after an "incubation" period of several days—took place at temperatures from about 5° C. to 27° C.

This living material was useful in affording a comparison with examples of the perithecial stage obtained from bushes in the open in the spring, *i.e.* after it had "wintered." In all cases, so far, such "over wintered" material, which has been obtained from N., Mid., and E. Kent[2], proved in February or later, to be dead. In such material the perithecium on being pressed open usually exudes drops of an oily nature; the ascus is not turgid, and is often more or less crumpled; the ascospores are filled with some oily material, staining pink with alkannin. No development can be induced on "incubation" at those temperatures which cause living perithecia to dehisce and discharge their spores, and it is clear that such perithecia are dead.

It seems clear, therefore, that some amount of the perithecial stage of the American gooseberry-mildew which is produced in this country either does not reach maturity or does not survive the winter.

[1] Salmon, E. S. Observations on the Perithecial Stage of the American Gooseberry-mildew (*Journ. Agric. Sci.*, VI, p. 187, May, 1914).

[2] Most of this material was kindly sent to me by Mr F. G. Cousins, Inspector for American gooseberry-mildew for Kent.

It is possible, but I think very unlikely, that in these cases where an examination in the spring showed only perithecia with dead asci that all the mature (living) perithecia had fallen previously to the ground. It seems far more probable that this material had never reached that stage of development at which the perithecia can remain alive through the winter. If so, the reason for this failure to mature may be due to the influence of new factors which the mildew encounters in this country —such as the "constitutional" characters of European varieties of gooseberries, or to the weather conditions obtaining in this country in the late summer or autumn. It may possibly prove to be the case that it is only the perithecial stage which is formed early in the season, reaching maturity about July or August, that is really dangerous, and that later-developed perithecia do not survive the winter.

It would of course be unwise to generalise from observations made so far on material obtained in one season only; but there seems clear evidence that both the fruit-grower and the official administrators of the American Gooseberry-mildew Orders have a new fact to reckon with, viz. the natural death, before the spring, of some amount of the perithecial stage of the American gooseberry-mildew.

Postscript. Since the above was written, I have had the opportunity of examining further "over wintered" material of *S. mors-uvae* collected at the end of April and during May.

The first lot of material collected at the end of April, was kindly obtained for me by Mr Gibson (Inspector for American Gooseberry-mildew for Surrey) from Farnham, Newdigate, and Witley. Thirty-four shoots bearing patches of the perithecial stage were sent; these were all closely examined. Twenty-two shoots bore patches of deep-brown persistent mycelium, which on examination proved to be either quite barren with no perithecia, or with just a few (dead) perithecia. The appearance of the barren patches suggested that no perithecia had ever been formed (*i.e.* that the development of the winter stage had been stopped), and not that the perithecia had fallen out from them, since the densely interwoven mycelial patches showed—in many cases at all events—no signs of having been worn thin or disintegrated under the action of weather conditions; in a few cases the mycelial patches may have been partly worn away as the result of "weathering." On more than 50 per cent. of these diseased shoots there was a completely barren, although dark brown, mycelium.

In the remaining twelve examples perithecia had been produced abundantly on the shoots, but in no case was a living ascus found inside

any perithecium. In several cases the perithecia had apparently never reached full development, since the ascus was not the normal size; in those cases where a full-sized ascus was present, it was without exception shrunken and obviously dead, and the ascospores, which contained oil drops, were evidently undergoing a process of degeneration.

On May 4 a commercial gooseberry plantation of "Berry's Early" near Rodmersham, Kent, was visited at a time when the American gooseberry-mildew was just beginning to appear for the first time this season. A number of bushes were found with the (conidial) "summer-stage" of the mildew developing—mostly on the young, green berries. In a considerable number of cases—perhaps in the majority of cases—the affected berries were in close proximity to portions of last year's shoots which were badly infested with the ("over wintered") perithecial stage. On microscopical examination, however, of nine of these shoots —*i.e.* where mildewed berries occurred close to the winter-stage formed in 1913—all the perithecia appeared to be dead, the ascus being either shrivelled or empty, or when containing ascospores the ascus was not turgid, and the spores were full of oily degeneration-products. The perithecium on being pressed open usually exuded drops of some oily substance.

On other branches of the bushes which bore the mildewed berries, and also on other adjoining bushes where no mildew occurred yet, the perithecial stage of 1913 could be found not uncommonly on some of the young shoots (although all the bushes had been "gone over" twice in the process of "tipping"). As in the above-noted cases, the perithecial stage consisted of the dark brown persistent mycelium, often considerably worn away by "weathering," and hundreds of closely aggregated perithecia. Thirty-two of these shoots with the perithecial stage were examined and not one perithecium could be found with a living ascus. The experiment was made of incubating some of this material at 27° C. but no change resulted.

On May 6 a commercial plantation of "Cousin's Seedling," near Sandwich, Kent, was visited. This plantation was so virulently attacked by the mildew in 1913 that practically all the young shoots on every bush became infested with the perithecial stage, and this also was developed on nearly every berry—the whole crop was lost, not a single berry being fit to pick. An examination on May 6 showed that the disease was just re-starting for the season; from 40 % to 50 % of the bushes (250 in number) bore a few berries with small patches of the (conidial) "summer-stage" on them. In a few cases young shoots more or less plentifully infested with the perithecial stage of 1913 were

closely adjacent to these mildewed berries. Nine of these shoots were microscopically examined, but no perithecium containing a living ascus was found. In the majority of cases the ascus was empty and shrivelled; in the few cases where ascospores occurred, the ascus was not turgid, and the spores were full of oily contents and evidently undergoing a process of degeneration. In a very few cases the perithecium contained the spores of the parasitic fungus *Ampelomyces quisqualis* (*Cicinnobolus Cesatii*), but it was clear that the mildew had not been parasitised to any appreciable extent. With regard to the bushes generally, the mildewed berries were found either on branches from which all the young wood (which had probably been diseased) had been cut away, or on spurs on quite old wood.

Since there is no evidence that in these cases these primary infections had been caused by ascospores from the "over wintered" material still present on some of the shoots, the explanation must be looked for in another direction. There are two ways by which infection by ascospores could have occurred. As I have pointed out[1], perithecia may begin to fall to the ground in August from infested berries and, to a less extent, from infested shoots. With regard to this particular plantation, all the berries (as noted above) became very badly infested: they were not removed by the grower until late in August—by which time not only must thousands of perithecia have fallen to the ground, but many of the infested berries had fallen or been scattered by birds; there must therefore have been a heavy infestation of the soil. If, however, the primary infections which were taking place in May had been caused by ascospores arising from the soil, one would have expected to find the majority of the mildewed berries on the lower branches of the bush, *which was certainly not the case; the infected berries being nearly always on the upper branches.*

The second way by which infection could have been caused is as follows. The "tipping," *i.e.* the removal of the infested shoots, was not done until the end of October or beginning of November; by this time a considerable mass of perithecia must have dropped from the perithecial patches. Many of these perithecia would doubtless lodge in the crevices of the bark, or between the bud-scales, etc., and assuming that these perithecia were mature ones capable of remaining dormant through the winter, these would on liberating their ascospores infect the adjacent berries. This theory, to which on the whole I incline, would account for the fact that the berries in the upper part of the bush were first attacked.

[1] *Journ. Agric. Sci.*, VI, p. 187 (1914).

POTATO DISEASES.

By A. S. HORNE.

Over seventy years have elapsed since C. E. P. von Martius[1] set to work to investigate potato disease in Germany and M. J. Berkeley[2] began his observations on the potato murrain, contributed to the *Journal of the Royal Horticultural Society* in 1846. These early observers recognised that potato disease consisted of several distinct maladies some of which they attributed to fungal organisms, but their knowledge of the diseases and fungi was of necessity incomplete. Von Martius noticed several diseases, notably Stockfäule (gangrène sèche or dry-rot), considered to be due to one of the Mucidineae—*Fusisporium solani*; Kräuselkrankheit (la frisole or curl), and Rände (gale), prevalent in the calcareous lands of Thuringia, Bavaria and in Austria. Payen[3] records in 1853 that *Rhizoctonia violacea*, the cause of the disease known in France as mort du safron of the lucerne and sanfoin, could also attack the potato.

The disease known in France as the maladie de la pomme de terre, in Britain as the potato murrain, was regarded by Montagne, Morren, Berkeley, Lindley, Payen and others as due to the fungus *Botrytis infestans* known later as *Phytophthora infestans*. The means of combatting the malady adopted in Payen's time were attention to the soil and drainage, the choice of varieties that appeared to have the best chance of escaping the disease, in the preparation of tubers to be used as seed—tubers to be planted should be exposed to dry air and light for some days before planting, whilst a wash of copper sulphate solution similar to that used for grain at that time was recommended—the rotation of crops, and the effect of autumnal planting was studied. It remained for De Bary (1861—1876) to present the first clear account of the life-history of *Botrytis infestans* and to finally settle its position among

[1] C. E. P. von Martius in *Die Kartoffel Epidemie der letzen Jahre oder die Stockfäule und Rände der Kartoffeln* 1842.

[2] M. J. Berkeley in *Journal of the Royal Hort. Soc.*, I, p. 9 (1846).

[3] Payen in *Des Maladies des pommes de terre*, Paris, 1853.

fungi. About the year 1885 the remedy bouillie bordelaise—bordeaux mixture—used in the first instance and chiefly owing to the efforts of Millardet, to combat the vine mildew in France, was adopted for other plants and amongst others the potato. Under the name Stockfäule (gangrène sèche), Martius probably confused the dry-rot disease, now known to be due to Fusarium, and the old potato disease or murrain caused by *Phytophthora infestans*. This is not surprising since Fusarium rot almost invariably supervenes after the attack by Phytophthora. Kräuselkrankheit, frisole or curl corresponds to the modern Blattroll-krankheit or leaf-roll, but the name Kräuselkrankheit appears to be now used more frequently for a type of curl with crinkled leaves. Curl is a disease of very long standing on the mainland of Europe and in this island but it has caused much consternation on the Continent during the last decade and has recently become a new potato problem for investigators in the United States. Records of its occurrence in Britain are to be found in the memoirs of the Caledonian Horticultural Society[1] of one hundred years ago. The gale, or canker disease as it should now be styled, is still prevalent in Europe and has been detected recently in South Africa[2] on potatoes forwarded to Rhodesia from Britain, and in America. The true nature of the canker organism, *Spongospora solani*, was established by Brunchorst[3] in 1886.

The most important additions to the list of British potato diseases since Berkeley's time are the maladies known as tumour and sprain.

The occurrence of tumour in Britain can be traced back as far as 1878 but the cause of the disease was not known until 1896, when an intracellular parasite was discovered by Schilberszky in material said to have been received from Upper Hungary and named by him *Chrysophlyctis endobiotica*. Chrysophlyctis was thrice described within the space of a few weeks in England in 1902, was chronicled as a Shropshire scourge in 1908 and scheduled under the Destructive Insects and Pests Act of 1907 in the same year.

Sprain, recorded by Frank[4] under the name Buntwerden or Eisenfleckigkeit in the list of diseases enumerated by him in *Kampfbuch* in 1897, and only recently definitely separated as an entity from the tangle of things insufficiently understood, is in all probability of long standing in Great Britain.

[1] Thomas Dickson in *Mem. Caled. Hort. Soc.*, I (1814).

[2] J. B. Pole-Evans in *Trans. Dept. Agric. Farmer's Bull.*, No. 110 (1910).

[3] J. Brunchorst in *Bergens Museums Aarsberetning* (1886).

[4] Frank in *Kampfbuch gegen die Schädlinge unserer Feldfrüchte* (1897).

Various bacterial diseases of the potato have been described during the last twenty-five years. In 1890 Prillieux and Delacroix[1] recorded a bacterial disease attacking the stem of the potato. Other bacterial maladies were subsequently described by Erwin F. Smith[2] in the United States (1896); Iwanoff[3], in Russia (1899); Harrison[4], in Canada (1906) and by Miss Dale[5] (1912). The disease known as black-leg or Schwarzbeinigkeit, which is of sporadic occurrence in Great Britain, has been attributed to various bacteria by different investigators. Frank[6] isolated a bacterium which he called *Micrococcus phytophthorus* (1899); Appel[7] (1902 and 1904), *Bacillus phytophthorus*, which is possibly identical with Frank's organism; C. J. J. van Hall[8], in Holland (1902), *B. atrosepticus*; Pethybridge and Murphy[9], in Ireland (1911), *Bacillus melanogenes*. Harrison's disease possibly belongs to this group.

On the American continent considerable attention is being given to two comparatively recently described fungal diseases—potato wilt, due to *Fusarium oxysporium*, described by Erwin F. Smith and Deane B. Swingle[10] in 1904, which is widespread in America, but, according to W. A. Orton[11], absent from Europe; and Verticillium wilt, due to *Verticillium alboatrum*, described by Reinke and Berthold[12] in 1879, present in America and Europe. Verticillium wilt has recently been recorded in Ireland by Pethybridge[13].

Potato collar-rot caused by the Basidiomycete, *Hypochmis solani* Prill. and Del. occasionally occurs in Britain.

The problem of potato scab has become an increasingly important one in the United States. The American scab is said to be caused by an organism isolated by Thaxter[14] (1890) who named it *Oospora scabies*

[1] Prillieux and Delacroix in *Comptes rend.*, CXI (1890), p. 208.

[2] Erwin F. Smith in *U.S. Dept. Agric. Div. Plant Path. Bull.*, 12 (1896).

[3] Iwanoff in *Zeitschr. f. Pflanzenkrankheiten*, IX (1899), p. 129.

[4] Harrison in *Centralblatt für Bakt.*, II, Abt. XVII (1906), p. 34.

[5] Elizabeth Dale in *Annals of Botany*, XXVI (1912), p. 133.

[6] Frank in *Centralblatt für Bakt.*, II, Abt. V (1899), p. 98.

[7] Appel in *Arb. a. d. biol. Abt. a. Kais. Gesund*, II (1902), p. 373; III (1904).

[8] C. J. J. van Hall in *Bijdragen tot de Kennis der bakterieelle Plantenziekten*, Diss., Amsterdam (1902).

[9] Pethybridge and Murphy in *Proc. Roy. Acad.* XXIX, sec. B, No. 1 (1911).

[10] Erwin F. Smith and Deane B. Swingle. *U.S. Dept. Agric. Bur. Pl. Ind. Bull.*, 55 (1904).

[11] W. A. Orton in *U.S. Dept. Agric. Bur. Pl. Ind. Bull.*, 64 (1914).

[12] J. Reinke and G. Berthold. *Die Zersetzung der Kartoffel durch Pilze.* Berlin (1879).

[13] G. H. Pethybridge in *Jour. Dept. Agric. and Tech. Instruc. Ireland*, XIII, No. 3 (1913), p. 23.

[14] R. Thaxter in *Conn. Agr. Expt. Sta. Rept.* (1890), p. 81.

(Mucidineae), but G. C. Cunningham[1] (1912) suggests its transference to the genus Streptothrix (Schizomycetes) and H. T. Güssow[2] refers it to Actinomyces. B. F. Lutman[3] (1913) has described the pathological anatomy of this scab. To what extent the British scab is due to *Oospora scabies* has yet to be determined.

A disease recently described by the writer[4] and named bruise, owing to the occurrence of greyish or black areas in the flesh of potato tubers which renders them unfit for culinary purposes, appears to be of a physiological nature and is perhaps often occasioned by growing potatoes in poor or insufficiently cultivated land.

Besides the fungal and physiological maladies, there are of course several pests on the animal side. The Colorado beetle scourge of the United States is fortunately not prevalent in these islands. The tuber-boring wire-worm, however, is frequently troublesome. The very much neglected subject of insects injurious to the potato foliage has been recently studied by Professor H. Maxwell Lefroy and the writer and the results obtained will be soon communicated to these Annals.

I propose now to consider as far as possible in correct perspective only those problems, the insect question excepted, that are of considerable economic importance at the present time in Great Britain.

Tumour.

The disease caused by *Chrysophlyctis endobiotica*—the tumour organism—has claimed considerable attention during the last few years, firstly owing to reports of an alarming kind relative to the virulence of this parasite and fear lest it might spread and eventually ruin the potato-growing industry ; and secondly, owing to the stringent measures taken by other countries, alarmed by reports of the prevalence of the disease here, against the importation of British-grown potatoes. According to the Report[5] issued by the Intelligence Division of the Board of Agriculture and Fisheries, 1911–1912, the actual loss occasioned to the potato harvest here is very slight indeed, since the report states : "There are probably scarcely five hundred acres in all England which are under cultivation for potatoes as a field crop which are liable to be affected while even in these the proportion of diseased tubers is

[1] G. C. Cunningham in *Phytopathology*, II (1912).

[2] H. T. Güssow in paper read before *Assoc. Econ. Biol.* London. (Easter, 1914.)

[3] B. F. Lutman in *Phytopathology*, III (1913), p. 255.

[4] A. S. Horne in *Jour. Roy. Hort. Soc.* XXXVIII, p. 40.

[5] Board of Agric. and Fish. *Annual Rept. Intellig. Div.*, Pt. II (1913), p. 24.

generally trifling." Owing to the regulations adopted by other Governments, however, the indirect loss to potato-growers is very considerable.

The question of the degree of virulence possessed by this organism needs searching analysis and the following points may be enumerated in this connection:

(1) Tubers planted in experimentally infected soil have produced without fail plants bearing diseased tubers (M. C. Potter).

(2) Diseased tubers have been produced year after year, irrespective of the kind of season, in soil once infected (M. C. Potter).

(3) Several varieties of potato were affected when planted in Potter's experimentally infected soil.

(4) The Report issued by the Intelligence Division, 1911–1912, states that in spite of the exceptionally dry season in 1911, the disease in all the badly affected places was as manifest as ever even though it was not observed in the less badly attacked districts.

(5) According to the Report, some varieties are practically immune to Chrysophlyctis.

It may be gathered from the Report that the disease is largely confined to cottage and allotment gardens. Now in gardens of this type, frequently ill-kept, where potatoes are grown year after year without rotation, *canker* also exhibits its worst form, rendering potatoes worthless and unsightly (see *Journal of the Royal Horticultural Society*, vol. XXXVII, figs. 101, 102). Is Chrysophlyctis, in this country, really more virulent in character than the canker parasite, *Spongospora solani*, or is the supposed greater virulence merely apparent owing to the absence of sufficient information on the canker side?

The life-history of Chrysophlyctis is moderately well known, nevertheless several important problems remain to be solved, such as (1) the exact nature of the bodies penetrating the tissue and the method of penetration; (2) the mode of existence for a prolonged period in the soil; (3) the conditions which favour or inhibit infection.

It is known that the fungus forms resting bodies (sporangia) in the tubers which when returned to the soil are capable of passing the winter there and may perhaps rest for years in the soil without losing the power to germinate. These sporangia are therefore a prolific source of infection and it is important to realise that infection can be brought about by their means in the following ways:

1. By planting diseased tubers.
2. By planting not-diseased tubers removed from infected soil.

3. By planting not-diseased tubers that have been in contact with diseased or not-diseased tubers from an infected soil.

4. By transference of soil from an infected area by some means or other, even though actual disease be not present in that area.

Every possible precaution should of course be taken to prevent the dissemination of these infective bodies, and the destruction of all diseased material is a reasonable and sound requirement.

Questions naturally arise as to how the disease can be fought *in situ* and the following issues need urgent attention:

1. The possibility of devising some treatment for sound tubers raised on infected soils.
2. The experimental treatment of infected soils.
3. Extended experimental work with varieties possibly immune.

The subject of resistance to Chrysophlyctis is an extremely important one. A high degree of resistance for certain varieties is claimed in the Report issued by the Intelligence Division and it is stated therein that the varieties when planted on infected land in several districts proved highly resistant. This matter needs keen attention under more searching experimental conditions in different localities and seasons.

The Phytophthora problem.

Although *Phytophthora infestans* is still the cause of the greatest financial loss through actual damage to the potato harvest in Great Britain, and in spite of the mass of literature that has arisen in connection with this subject, several important matters still need urgent attention. Of these, the manner in which the infection of the potato crop is occasioned each year, will be first considered.

Marshall Ward[1] held the view, by analogy with the behaviour of many rust fungi, that the mycelium of the fungus could remain dormant in the tuber through the winter and bring about infection in the following season:

"More commonly however the tubers are beginning to ripen when the hyphae reach them and the mycelium goes to sleep—passes into a dormant state—between the cells of the ripening tuber."

The expression "dormant mycelium" is not necessarily restricted to mean mycelium hibernating in tubers showing disease, but admits the presence of mycelium in healthy tubers. Hence Marshall Ward

[1] H. Marshall Ward in *Diseases of Plants*, p. 75.

advised that potatoes should never be saved for seed from plants of a diseased crop.

Massee[1] adopted and elaborated this theory claiming that outbreaks of Phytophthora and epidemics over wide areas are due to hibernating mycelium. He was led to the peculiar view of the wholesale migration of mycelium from the parent tuber to its own offspring:

"The great bulk of disease is due to hibernating mycelium against which no remedy is known." "I have proved by repeated experiments that when a diseased tuber is planted, the mycelium from such tuber passes into the young potatoes which also become diseased."

"The produce of a diseased tuber is always diseased." "Potatoes from a crop known to be diseased should never be used for seed."

These authors were committed to a most pessimistic outlook upon the whole problem.

Now as a matter of fact, sections of healthy tubers invariably fail to show the mycelium of Phytophthora in its accustomed place—the air spaces—whilst microtome preparations through the junction of diseased and healthy tissue, show that the mycelium present in the diseased portion ceases at the boundary line between the two. The question of dormant mycelium in the sense used by Marshall Ward, therefore, passes beyond the pale of argument or controversy. The conclusion is reached that the disease is not carried by entirely healthy tubers unless the mycelium reside saprophytically in the skin, and of this there exists no positive evidence. Attention should therefore be concentrated upon diseased tubers no matter how slightly diseased, as a means of causing an epidemic. The first question that naturally arises is this, can the mycelium present in diseased tubers maintain itself through the winter until the planting season begins? Pethybridge states definitely that it can and the writer can confirm his statement so that a positive answer must be returned. Secondly, does this fact explain the infection of crops each season? Upon planting diseased tubers the fungus might be returned in a living condition to the soil and remain there to infect the young tubers, but no evidence has been obtained on this point. On the other hand, the fungus might pass from the planted tubers to the young shoot. The evidence available in this connection leaves much to be desired.

Massee[2] claims to have found Phytophthora present upon shoots originating from diseased sets presumed to contain this fungus.

[1] G. Massee in *Diseases of Cultivated Plants and Trees*, p. 125.

[2] G. Massee in *Kew Bull.*, 4 (1906).

Pethybridge[1] found that one plant out of nine raised from diseasėd sets, planted in a cool greenhouse " produced a shoot only 2 or 3 inches high which quickly became diseased from below upwards and soon died. Doubtless the mycelium had entered the shoot from the parent set." The plant was removed but Phytophthora was subsequently detected on several plants in this house. Pethybridge states " although absolute proof is lacking, it seems practically certain that the plants whose foliage became diseased must have become infected by means of ' spores ' from the single diseased sprout sent above ground by one of the diseased sets." It is not made evident from the description that Phytophthora had been actually observed upon this single diseased shoot and its upward course from the tuber traced, so that the experiment as described does not demonstrate that the fungus developed with the developing sprout. This important point still needs to be settled and evidence obtained from experiments in greenhouses would need to be supported by evidence from extensive field experiments.

That diseased tubers may produce healthy plants is a matter of common knowledge. The crucial question in relation to the infection of crops is whether and, if so, in what proportion, will diseased tubers yield diseased plants. A single diseased plant as everyone knows becomes a centre of infection and the possible source of an epidemic, since the fungus possesses the power of rapid growth, rapid sporulation and the spores are rapidly disseminated. It is important to realise that a single diseased plant in, say, a twenty-acre field of potatoes might start an epidemic. What then are the chances for, or against, the occurrence of one bad plant in a twenty-acre field ? Results which show complete failure to obtain Phytophthora in the aerial parts produced by diseased potatoes must be received with some reserve, owing to the small number of tubers planted and since information is usually lacking as to whether the fungus was actually observed or demonstrated to be living or even present in the tubers when planted.

There are of course other possible methods whereby an outbreak in spring might be occasioned but these have either no positive evidence in favour of them or they have not yet been investigated.

Payen[2] in 1853 records that he had observed *Botrytis infestans* on the tomato and since Payen's time the fungus has also been recorded as occurring upon various wild Solanums. According to Howard S.

[1] G. H. Pethybridge in *Sci. Proc. Roy. Dub. Soc.*, XIII (N.S.), No. 2 (1911), p. 21.

[2] Payen in *Des maladies des pommes de terre.* Paris (1853).

Reed[1] (1912) the Phytophthora of tomato is identical with that of the potato. The formation of conidia upon hosts other than the potato may therefore prove to be a source of infection and the cause of an epidemic.

A very attractive solution appeared to be in the possible discovery of and wide occurrence of sexually-formed resting spores such as occur in the related fungus Pythium. Oospores of Phytophthora are now known, and chiefly owing to the work of Clinton[2] who obtained them, in pure cultures of the fungus in artificial media. In spite of diligent and persistent search by numerous investigators, oospores, however, have not yet been discovered within or upon the potato plant so that they do not appear to be formed upon this particular host. There seems to be no reason, of course, why oospores should not be found upon some other host and be discharged to the soil from the host, but no extensive study in this connection has yet been made.

Another point that needs to be determined is whether the mycelium of Phytophthora can maintain existence in the soil from the autumn until the following potato-growing season, either parasitically in the many small potatoes remaining in the soil or saprophytically in fragments of tuber and pieces of skin.

Another phase of the Phytophthora problem must now be considered—the actual occurrence and mode of occurrence of the disease.

Infection of the foliage may be brought about in two ways. Firstly, the mycelium present in a planted diseased tuber might extend into the growing sprout and thence into the leaves and infect them. Secondly, the leaves might be directly infected by means of conidia, wind borne or brought by some other means. In this case the zoospores liberated from the conidia germinate forming mycelium which enters the tissue of the leaf and causes it to droop and die. Spraying when properly performed has been found an efficient remedy against the premature death of the foliage; the disease is checked and the growth of the plant is actually stimulated.

Tuber infection also may be brought about in two ways. Firstly, in the case of plants with infected foliage the mycelium could extend into and along the vascular bundles ultimately reaching the growing tubers, but this method does not appear to be of frequent occurrence. Secondly, the growing tubers might be attacked directly from the soil. Irrefutable evidence of the frequent occurrence of this mode of infection

[1] Howard S. Reed in *Phyt.* II. (1912), p. 250.

[2] G. P. Clinton in *Science*, N.S. XXXIV (1911), p. 744.

may be obtained by scanning diseased tubers in the field when they are lifted. In such cases the following points furnish a guide : (1) the stalk-end of the tuber when cut across may be entirely without discolouration, (2) the brown marks in the flesh of the tuber caused by the fungus, frequently do not extend from the skin as far inward as the principal cylinder of vascular bundles, (3) the brown shallow areas of diseased tissue near the skin are often quite isolated and sometimes limited to the neighbourhood of an eye.

The subterranean attack might be occasioned by :

(1) Mycelium, if it exists.
(2) Oospores, if they exist.
(3) Zoospores.

1 2

Fig. 1. External view of tuber attacked by Phytophthora from the soil.
Fig. 2. Healthy tuber with clean skin for comparison with Fig. 1.

As already stated no evidence has yet been obtained relating to the presence of mycelium or oospores in the soil. With regard to zoospores, it may be fairly reasoned that if the foliage is attacked, the conidia formed on the leaves can be carried by the wind and distributed not only to neighbouring plants but on the surface of the soil. During a period of heavy rain the conidia or zoospores would be carried into the soil and eventually reach the surface of the tuber and penetrate it. This matter still needs adequate experimental proof.

One of the chief puzzles afforded by the Phytophthora problem is afforded by the case of field crops which are badly diseased when lifted

although no disease had been detected in the foliage. An instance occurred in 1909, on a large field in Durham County. I observed no Phytophthora on the foliage during the season, but at the lifting, there were very few plants without one or more diseased tubers (Fig. 1). The uniform infection of the field seemed extraordinary. It could be accounted for in three possible ways:

(1) Phytophthora may have been present on the plant, but inconspicuous and escaped observation.

(2) The soil may have become infected with wind-blown conidia from some potato field in a neighbouring farm.

(3) The soil may have been infected with mycelium or oospores, if such do exist in the soil.

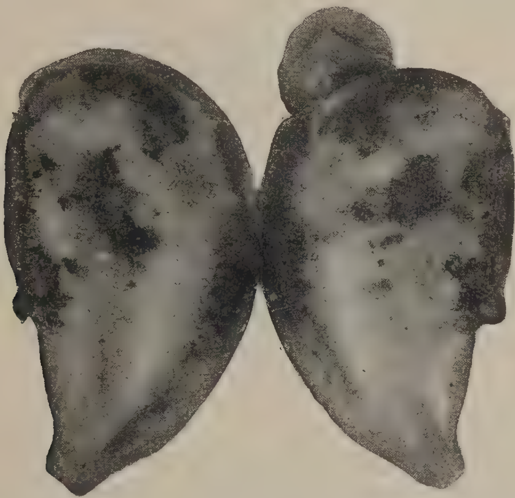

Fig. 3. Tuber cut open to show the brown rot caused by Phytophthora.

The whole Phytophthora problem needs very careful study with a view to determining whether there is or is not a definite soil-factor, occasioned by the power of the fungus to rest or live in the soil. If it can be shown that there is not, the prospect of eradicating the disease is not hopeless since effort could be concentrated in the selection of seed tubers and widespread and efficient treatment of the foliage.

A third line of enquiry which relates to the conditions that favour the development of the blight fungus and involves two issues—(1) blighted tubers, (2) blighted foliage—will be pursued in a later paper.

Sprain.

Sprain has caused considerable loss to potato-growers within the last few years, affecting certain varieties in the field crop, often rendering the yield practically unsaleable.

Sprain includes two forms of tuber-disease—blotch (internal disease) and streak (sprain) which have not yet been proved identical. Blotch, under the name internal disease, is reported to have been under investigation by Marshall Ward nearly twenty years ago but I have been informed by Prof. Seward that Marshall Ward left no records of such investigation. The word sprain, as used in the north, is applied to tubers with internal, brown, streak-like markings. This word has been adopted by the Board of Agriculture to include both blotch and streak.

Fig. 4. Section of a tuber showing internal disease or blotch.

Under the name of Buntwerden or Eisenfleckigkeit, sprain has long been known on the continent of Europe and recognised as a distinct disease not caused by fungal organisms. In Britain blotch and streak were supposed by some authors to be either directly or indirectly due to the late blight fungus and by others to the dry rot organisms. These suppositions, however, as the writer[1] has recently shown, cannot be upheld.

The importance of ascertaining whether the disease is caused by an organism from the practical point of view is evident since the question of the infection of crops is involved. Disease might arise from planting diseased tubers or owing to the presence or transference of infected soil. Frank considered that Buntwerden was due to the prevailing conditions of soil and climate but his point of view is founded upon the

[1] A. S. Horne in *Jour. Agric. Science*, III, Pt. 3 (1910).

apparent absence of an organism and insufficient experimental evidence. There are three experimental methods of attacking the problem: (1) that of analysis by means of field experiments, (2) that of attempting to isolate pathogenic bacteria from diseased tubers, (3) that of analysis of the bacterial flora of soils from "sprained" areas. At present only the first of these methods has been seriously adopted by the writer with the following chief results:

(1) In four consecutive years a certain proportion of diseased tubers was obtained in the yield from diseased sets upon every occasion when diseased sets were planted, in Northumberland (1909, 1910), Devonshire (1909–1910), Ireland (planted by Dr Pethybridge, 1910), Chelsea (1911), and Wisley (1912).

(2) In the fifth year at Wisley (1913) no diseased tubers were obtained in the yield from diseased sets.

(3) In 1909 the writer selected disease-free tubers of the Sutton Flourball variety from a sack containing a high percentage of diseased potatoes given to him for experimental purposes by Messrs Sutton. The issue from these selected tubers has proved healthy in each successive year—1909, Northumberland and Devon; 1910, Northumberland, Devon and Ireland; 1911, Chelsea; 1912, Wisley and Walton-on-Thames (in sprained soil); 1913, Wisley.

(4) Disease-free tubers of the susceptible variety, Duke of York obtained from a locality where sprain is absent, yielded a diseased crop when planted upon "sprained" land, at three different stations in Scotland in 1911.

(5) Tubers selected disease-free from the produce raised in Scotland in 1911, yielded only a few diseased tubers at Wisley and none at Oxshott in 1912 and none at Wisley in 1913—but in this season diseased sets produced healthy tubers.

It is clear that "sprain" is influenced a great deal by conditions of soil and weather, but it is by no means certain that it is entirely due to these conditions as Frank supposed. Analyses of soils from different centres where considerable harm had been done to the potato crop by internal disease showed that they were exceptionally poor in phosphates, potash and lime, being moorish, sandy soils, but sprain is by no means confined to such soil, and moreover selected tubers of susceptible varieties when planted experimentally on similar soils have not taken the disease. It is exceedingly difficult to interpret all the evidence entirely on a physiological basis. But the evidence is not at all incompatible with the theory of the existence of an organism-factor—the organism

being of bacterial nature. The apparently conflicting evidence, such as is production of a healthy crop from susceptible varieties upon "sprained" land and the occurrence of healthy issue from diseased tubers, is paralleled among the organism-caused diseases. Thus the potato crop including that obtained from the susceptible varieties may not be appreciably affected by the canker organism although this parasite is actually present in the soil, whilst the production of healthy plants and potatoes from sets affected with Phytophthora is, as I have already stated, of common occurrence. The failure to obtain sprain in the vegetative generations proceeding from tubers originally selected as disease-free from diseased stock of susceptible varieties when planted in soils of several kinds in different localities seems opposed to a purely physiological explanation.

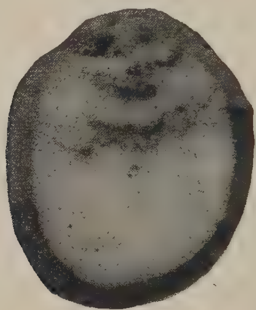

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Fig. 5. Section of a tuber showing sprain or streak.
Fig. 6. Another section of the same tuber.

Pending attempts to isolate pathogenic bacteria, additional evidence might be gained by attempting to infect potatoes with sprain through the agency of soil derived from lands liable to it.

In the meanwhile the best means of preventing loss through sprain will be those which have certainly occurred to skilled potato-growers; firstly, to avoid as far as possible the use of "sprained" tubers for seed, and secondly, to cultivate varieties which are the least susceptible to the disease. The most thorough method of procedure would be to obtain an accurate record of the distribution in Britain of the lands liable to sprain, and to carry out potato trials in different localities where the disease is most troublesome, with the object of discovering the most suitable and relatively sprain-immune varieties for the district about each experimental area.

Fusarium disease.

Two types of Fusarium disease are recognised by Orton[1]. The first, Fusarium wilt, caused by *Fusarium oxysporium* described by Smith and Swingle in 1904, affects the field crop and is one of the most serious diseases of the potato with which the United States has to deal. According to Orton, there is no evidence that the Fusarium wilt occurs in Europe. Wollenweber[2] has been able to differentiate the *Fusarium oxysporium* of Smith and Swingle from other potato Fusaria and finds it to be distinct from any European form. The second or dry rot disease, according to Wollenweber's investigations, appears to be caused by one or more species of Fusarium. The dry rot Fusaria do not, as a rule, attack the tubers when in the soil, although they are certainly present there as shown by Miss Dale[3], who includes *F. solani* in the fungus flora obtained by her from sandy soils. Miss S. Longman[4] records that *Fusarium solani* attacked the potato plant in experimental plots at Reading in 1909, but cases appear to be of rare occurrence in Britain.

Fusarium becomes evident in the potato pit or store especially when potatoes are stored in a damp condition, a state of affairs often difficult to avoid in some potato-growing districts. A crop that has been attacked by Phytophthora or sprain is especially liable to suffer.

The question of the parasitism of *Fusarium solani* was fully discussed by Pethybridge and Bowers[5] in 1908. These authors state it is quite clear that the fungus is a true parasite capable of directly producing the disease in absolutely healthy potato tubers. The disease can be communicated therefore to healthy tubers in contact with diseased ones. A similar conclusion was arrived at by Miss Longman.

Curl.

"This disease, so far as I can learn, first began to be alarming to the growers of the potato, about thirty-five or forty years ago. Since that time, it has continued to engage the attention of many eminent agriculturists and gardeners"—Thomas Dickson, 6th March, 1810, in *Mem. Caled. Hort. Soc.* I (1814).

[1] W. A. Orton in *U.S. Dept. Agric. Bur. Pl. Ind. Bull.*, No. 64 (1914).
[2] H. W. Wollenweber in *Phytopathology*, v. 3, No. 1 (1913).
[3] Elizabeth Dale in *Ann. Myc.* x, No. 5 (1912), p. 471.
[4] Sibyl Longman in *Jour. Linn. Soc. Bot.*, XXXIX (1909).
[5] G. H. Pethybridge and E. H. Bowers in *Econ. Proc. Roy. Dub. Soc.*, I, Pt. 14 (1908).

"No plant disease in this generation has been the subject of such general discussion as that known in Germany as the 'Blattrollkrankheit' herein named 'Leaf-roll.' None has aroused greater difference of opinion as to its nature and cause, and no other single malady of plants is to-day receiving so much investigation by skilled pathologists

Fig. 7. Foliage from a plant of the President potato affected with curl showing the under surface of the leaflet exposed owing to the curl, small brown blotches and dead leaflet-ends.

as this. Possibly no disease which has appeared since the advent of *Phytophthora infestans* in the forties presents a greater menace to potato culture"—W. A. Orton, Feb. 10, 1914 in *U.S. Dept. Agric. Bur. Pl. Ind. Bull.*, 64 (1914).

By far the most important case of curl recently recorded in Britain has occurred in connection with the President potato, a variety imported from Germany and Holland on several occasions during the last few years. On land in the neighbourhood of Dunbar, the President yielded an enormous crop—fifteen tons to the acre—and produced only a small percentage of bad plants. But in certain other localities, this variety produced a high percentage of dwarfed plants with foliage of a light green colour or tinged with yellow or pink and leaves rolled upward and frequently much blotched as already described by the writer[1]. Quanjer[2], who has investigated curl in certain varieties in Holland, states that the phloem strands in the stem of leaf-roll plants are shrunken and lignified so that the translocation of food material to the tubers is interfered with. The bad plants produced by the President in Britain produced an exceedingly small yield of very small tubers.

Curl has often been attributed to fungi and notably Fusarium, Verticillium, and Macrosporium. Thus Appel originally believed that it was due to Fusarium and this view obtained for quite a considerable time and is held still by some authorities, notably Köch and Kormanth.

But abundant cases of leaf-roll have been recorded, as already pointed out by Sorauer, including the present case of the President, where no fungi are present. Macrosporium was present in the blotched foliage of the President, in the potato field in 1910, but since blotched foliage of a similar nature was produced in localities where Macrosporium was entirely absent from the plants, the disease could not be attributed to this or any other fungus.

It was next necessary to establish to what extent, if any, the condition of the foliage in bad plants might be brought about by injurious insects. Accordingly a joint enquiry into the subject was instituted by Professor H. Maxwell Lefroy and the writer, and yielded results which show that although the insect factor is of more importance in relation to diseased foliage than has been hitherto supposed, nevertheless this particular malady is not caused by insects.

But considerable light was thrown on the probable nature of the disease during the study of the plants raised from seed of the President for the purpose of insect infestations by Professor Lefroy and the writer at the Royal Horticultural Society's gardens, Wisley (1912–1913–1914), the Chelsea Physic Garden (1911–1912), and at Messrs Sutton's trial grounds, Reading (1912), and evidence was obtained which points

[1] A. S. Horne in *Jour. Roy. Hort. Soc.* xxxvi, p. 618 (1911).

[2] H. M. Quanjer in *Med. van de Rijks Hoogere Land-, Tuinen Bosch.*, Deel vi (1913).

conclusively to the non-parasitic nature of the disease. Hence the question of infection does not occur.

A similar conclusion has been reached by W. A. Orton from a study of leaf-roll in seedling varieties in the United States.

Professor Lefroy and the writer found that the seedling plants used for infestations exhibited considerable variability not only in the habit, shape of leaf, and other external characters but in physiological characters as evidenced by selection by the White Fly (Aleurodes) and by the uneven response exhibited by the plants when under similar experimental conditions. These physiological characters are not in any way associated with particular external plant features. The tubers themselves, as the writer[1] has pointed out, also exhibit considerable variability in shape, kind of eye, and other characters, whilst Doby[2] has recently shown that tubers from plants affected with leaf-roll give a higher reaction with respect to oxidase, peroxidase, and tyrosinase; also they had a slightly higher ash content and less starch and protein.

Taking everything into consideration it is very evident, firstly, that physiological variability plays an important rôle in the curl problem, and secondly, conditions of culture. There appear to be certain optima that favour the production of good plants, as at Dunbar in 1910, below these optima the percentage of bad plants increases. Pathological symptoms are the outward expression of the response made by particular plants to conditions which do not suit them.

The value of selection under the circumstances must now be considered. In the course of recent experiments, at Wisley, small tubers, whether from good or bad plants, produced bad plants as a rule tubers from bad plants being usually small, produced bad plants. Of greater importance, however, was the result obtained from tubers that had been specially selected as desirable for seed purposes, obtained from the Dunbar ground which produced a heavy crop in 1910. These tubers produced both good and bad plants and a high percentage of the latter. The occurrence of bad plants, however, did not bear any relation to any particular characters of the tubers which produced them. Selection becomes, therefore, an exceedingly difficult matter, since there appear to be no external tuber-characters that can be used as a guide in selecting favourable physiological plant-characters. Selection on the basis of favourable external characters (shallow eyes, etc.) leaves entirely to chance the selection of favourable internal properties.

[1] A. S. Horne in *Jour. Roy. Hort. Soc.*, XXXIX (1914), p. 596.

[2] G. Doby in *Zeit. für Pflanzenkrankheiten*, Bd. XXI, XXII (1911, 1912).

For this reason the percentage of bad plants obtained through a particular stock of the President might be greater than that obtained through the use of another stock and the total yield proportionally less—other conditions being similar.

Canker.

Owing to the serious notice given to potato canker, in a recent Bulletin issued by the United States Department of Agriculture, investigators in Great Britain may be compelled to devote considerable attention to this disease, although as already pointed out by the writer, the worst cases in this country are to be found in ill-kept gardens, whilst comparatively little damage is done to the potato harvest by canker. The tubers in the field crops are sometimes scabby but the scab is often less noticeable than the brown scab of unknown origin prevalent in many parts of the country. I. E. Melhus[1], the author of the United States Bulletin, devotes little attention to the comparatively trivial damage caused by the canker organism in Britain whilst prominence is given to the statements of serious damage to the potatoes in Ireland.

In Ireland canker is reported as causing considerable loss to the potato crop. Johnson[2] states "I have no doubt myself, that this Spongospora scab has a good deal to do with the miserable average yield per acre of potatoes in the west of Ireland. It is in some districts of Ireland as injurious to potatoes as finger-and-toe in Turnips," and Pethybridge[3] writes of the attacks caused by Spongospora, "they were particularly disastrous on those portions of the land which for special purposes have now been cropped for four successive seasons with potatoes, the cankerous form of the disease being extremely common."

Güssow[4] with regard to canker in Canada states "the disease should by no means be regarded lightly. Severe attacks occur when potatoes are planted year after year in infected land." The disease was also regarded seriously by Pole-Evans, in a circular issued by the Transvaal Department of Agriculture in 1910.

Pethybridge and Güssow specially note the occurrence of canker in land that has been cropped year after year for potatoes and it seems clear, from the published accounts of its occurrence in Ireland, that the

[1] I. E. Melhus in *U.S. Dept. Agric. Bur. Pl. Ind. Bull.*, No. 82 (April 6, 1914).

[2] T. Johnson in *Econ. Proc. Roy. Dub. Soc.*, I (1908), p. 453.

[3] G. H. Pethybridge in *Jour. Dept. Africa. Tech. Instruc. Ireland*, XIII, No. 3 (1913), p. 16.

[4] H. T. Güssow in *Phytopathology*, v, 3, No. 1.

disease in its worst form occurs in poor or badly cultivated land and is favoured by the wetness of the season. These points should be borne in mind in attempting to arrive at an estimate of the relative importance of the canker disease from an economic standpoint, and to avoid the danger of unduly exaggerating the danger of canker. It is surely undesirable that the potato industry in Britain should suffer more than absolutely necessary, and that other countries should lose by rejecting British-grown potatoes for seed which still rank amongst the finest in the world.

Fig. 8. Wart stage of potato canker.

Nevertheless the point of view and the attitude of investigators in the United States must receive consideration. Melhus points out that scabbiness is a more serious handicap in the American markets than in those of European countries, and further states that " If powdery scab (canker) should prove no more troublesome in the United States than it

has been up to the present in Europe, it would be rated as a disease of secondary importance as compared with late-blight or with Fusarium wilt. But there are reasons for fearing that it may become more prevalent here....It quite often occurs that introduced parasites are more destructive in a new habitat than in their native environment. Likewise it is not impossible that Spongospora may find the American varieties of potato more susceptible than the European sorts."

The prevalence of canker in many European countries and the Dominion of Canada has prompted the Department of Agriculture in the United States to extend for a time the Quarantine on foreign potatoes. The attitude of the United States in this matter may render it advisable to ascertain the distribution of canker in Britain as in the case of the tumour parasite, but statistics would be difficult to obtain and the process of recording would need to be spread over several years for numerous and obvious reasons.

The symptoms of canker have already been fully described by the writer[1]. The organism *Spongospora solani* Brunchorst, as in the case of Chrysophlyctis, can rest in the soil and there seems little immediate prospect of arriving at a soil remedy. Both organisms form resting bodies which are said to be capable of remaining for many years in the soil, but whether there is any other mode of subterranean existence is as yet quite unknown. Neither is it known exactly how the process of infection is carried out, whilst we are almost entirely ignorant of the conditions that favour or inhibit infection.

Some varieties of potato, which are more susceptible than others in a certain district, in other districts may be almost immune. Therefore generalisations from experiments in one locality only should be avoided and tests established at several experimental stations.

[1] A. S. Horne in *Jour. Roy. Hort. Soc.* XXXVII (1911).

A NOTE ON CELERY LEAF-SPOT DISEASE.

By F. J. CHITTENDEN, F.L.S.

The disease of celery known as leaf-spot, rust, or blight, due to the attack of the fungus *Septoria petroselini* var. *apii* B. and C., has spread with alarming rapidity over this country since it was first definitely recognised here in 1906[1].

An account of the disease and its spread, with notes on the fungus that causes it and its distribution in Europe and America, are given in the Journal of the Royal Horticultural Society[2] and it is there shown that much of the commercial "seed" offered for sale is infected with the fungus. The small black fruits of the fungus appear on the walls of the celery "seeds" and the pieces of stem to which they are attached with considerable frequency and may be readily seen by the aid of a lens. Experimental cultivation from fresh seed proved the contained spores to be viable and Klebahn showed[3] that spraying healthy plants with the washings from affected seeds led to the infection of the plants with the disease.

The author was led to suspect the seed as the principal, if not the only source of infection, by the curious distribution of the earlier attacks, the incidence of the disease on certain strains of celery, the absence of any records of attack upon wild plants, and the fact that so far as enquiry showed, the seeds from which the diseased plants had been raised had been purchased from one or two sources. Against it was the fact that all the earlier attacks had been noticed late in the year, generally from September onwards, though one or two attacks had been seen in July. At this season the disease had obtained such a hold upon the plants that spraying methods proved almost entirely inadequate to prevent its spread and total loss of crop frequently resulted. Later, attacks of a slighter nature were noticed nearer the beginning of the growing season and spraying with Bordeaux mixture at frequent intervals

[1] Chittenden, F. J. *Journal R.H.S.*, XXXII (1907), p. cxii.

[2] Chittenden, F. J. Celery Leaf-Spot, *Journal R.H.S.*, XXXVII (1911), p. 115.

[3] Klebahn, H. Krankheiten des Selleries, *Zeits. f. Pflanzenkr.* (1910), p. 4.

mitigated the severity of the attack[1], and in some cases proved a perfect cure.

When the paper on "Celery Leaf-Spot" appeared we were in possession of the knowledge that the disease was due to the fungus *Septoria petroselini* var. *apii* B. and C., that it was spreading rapidly and in a fashion that could best be explained on the assumption that the seed carried infection, that the "seed[2]" frequently showed the fruits of the fungus, that these fruits contained spores capable of germinating, and that plants sprayed with water containing these spores succumbed to the disease, but the actual infection of the seedlings from infected seeds had not been observed. We have recently been able to demonstrate this infection and to place this on record is the object of this note.

Seed showing the fungus fruits containing spores was sown in the ordinary way and the germination kept under observation. It was found that in many cases the pericarp remained attached to the cotyledons for a considerable time after they emerged from the soil and became green, and that many of the cotyledons turned yellow owing to the attack of the fungus which quickly produced fruit containing the typical spores. Only those seedlings which had grown from seed showing the fungus were attacked at this time and the pieces of pericarp attached to the diseased cotyledons showed the fungus quite clearly. Side by side with the diseased seedlings were others which were at this stage perfectly free from attack and which were developed from healthy seed. The chain of evidence that the seed carries the infection is therefore complete.

Whether there are any other modes by which the fungus maintains its infective powers from season to season, as, *e.g.* on diseased portions of plants thrown on the rubbish heap or dug into the ground, is not clear, but it is clearly a point of economic importance that seed-growers should take every care to save seed only from healthy plants. If this were consistently done the author feels sure it would do much to mitigate the severity of the attacks and it would probably result in stamping out the disease entirely.

The disease appears to spread more slowly during the seedling stage than later in the season and the attack is more localised on the plant. Diseased plants in September usually show the fruits of the fungus

[1] See for instance Salmon, E., in *Gard. Chron.* 1913.

[2] It ought perhaps to be noted that the commercial celery "seed" really consists of fruits or half fruits and therefore carries parts of the parent plant readily open to attack.

dotted very closely over the whole of the diseased leaves which become dull blackish-green in consequence, but the seedlings show, both on cotyledons and on foliage leaves, yellow spots extending to the leaf margin bearing the small black fruits of the fungus, and contrasting markedly with the bright green of the healthy parts of the foliage.

When the matter was first enquired into about 40 % of the commercial "seed" samples examined showed the presence of the fungus, now the percentage has risen to 90 %. The attention of seed-growers and seedsmen in this country has been called to the extent to which the infection has reached, and the danger to the crop from sowing seed containing even a small number of infected "seeds," and it is to be hoped that they will endeavour to produce "seed" free from infection. Experiments have been begun to see whether the fungus can be killed by immersing the "seed" in fungicides, as it no doubt can, and it has been shown that consistent attention to spraying with Bordeaux mixture (much more easily and safely carried out on plants grown for seed than in the growing of celery for market) will control the disease. It seems, therefore, probable that seed-growers have it within their power to provide their customers with clean seed.

It may be added that Celeriac, too, has fallen victim to the disease with increasing frequency during the past two years.

NOTES.

A MEETING of the Association was held in London on April 17th and 18th. Some of the papers read at the meeting appear in this issue and a complete list is attached. We regret that no complete account of the meeting has appeared in any paper but the accident which befell the Honorary Secretary three days before the meeting upset the arrangements including those made for reporting the papers and discussions. The chair was taken by the President, Professor Newstead, F.R.S., and after the election of members the following papers were read :—

Dr H. T. GÜSSOW. The Organism of Common Potato Scab. In the absence of the author this was read by Mr A. G. L. Rogers.

Mr A. S. HORNE. Potato Diseases.

Professor E. S. SALMON. Observations on the Perithecial Stage of the American Gooseberry Mildew (*Sphaerotheca mors-uvae*).

Professor PERCY GROOM. Brown Oak.

Mr A. G. L. ROGERS. The Phytopathological Conference.

Mr E. HARGREAVES. The Life-history and Habits of *Aleurodes vaporariorum.*

Professor R. S. MACDOUGALL. *Hylastes palliatus* and its rank as a Forest Enemy.

Mr E. E. GREEN read a recently published bulletin of the United States Department of Agriculture entitled "Economic Points in regard to the Migratory Habits of the House Fly."

Mr J. W. MUNRO. A Braconid Parasite of *Hylobius abietis.*

Mr F. J. CHITTENDEN. A Note on Celery Leaf-Spot Disease.

Mr H. WORMALD. A Bacterial Rot of Celery.

Mr R. A. WARDLE. Life-history Notes on two previously unrecorded Parasites of the Large Larch Sawfly.

Mr A. W. WESTROP. The Golf-green Maggot.

The PRESIDENT communicated a note by Mr A. D. WALKER on "The Migrations of the Coccinellidae."

The Scope of the Annals.

The *Annals of Applied Biology* has been founded to publish the scientific papers of the members of the Association and to represent as far as may be their interests. Its scope is as wide as the membership of the Association and we are not desirous of its falling into the narrow

rut of one limited subject. How wide its interests are to be, how extensive its scope, depends upon its contributors. We will endeavour to ensure the *Annals* reaching all who are interested in the subjects dealt with and we are securing a wide circulation outside our actual members.

We have already stated that purely systematic work in any group does not come within its scope ; nor does the enumeration of the flora or fauna of defined areas ; both are very amply provided for. We do however invite contributions in all branches of Applied Biology and efforts will be made to ensure that the *Annals* reach all centres of research in the subjects these papers deal with.

There is no desire to encroach on the spheres of influence of other journals and among our members are those who contribute to these journals ; we hope that papers will be read at the meetings which will perhaps be published in the *Journal of Agricultural Science* or elsewhere ; the Association does not claim the right to publish in the *Annals* all papers read at its meetings and we shall find a wide scope for the *Annals* without encroaching on the scope of other publications. We do hope that the range of subjects of our meetings and of our members may be so wide as to include workers in every branch of Economic Biology, whether they contribute to the *Annals* or not, and that the distinction between the scope of the meetings and membership and that of the *Annals* may be recognised.

The Association.

At the last meeting forty new members were elected ; there are, however, at least twice the total of our members in workers in Applied Biology who might reasonably be expected to become members. We hope that a large proportion of the potential members will become actual members : if our membership really embraces a large majority of workers and teachers in the Empire, the Association benefits, the individual member benefits and when the need comes, we may reasonably hope to be able to represent the interests of the whole body or of the individual in a satisfactory manner ; we do not propose to invite members to strike ; we are not a trade union ; we do not even propose to discuss the rewards given to scientists by the state, a subject that has considerably exercised a few prominent scientific men lately ; but a really representative Association is needed and can exert an influence attainable in no other way.

We hope also that the Association may be a focus for ideas and

knowledge; that members in distant parts of the Empire will send us notes and papers; that the originality developed by dealing with new problems may find expression in our *Annals*; and that we in England may be stimulated by the progressiveness of the Dominions and stirred by their newer and more thorough ways of tackling problems, born of the stress of circumstances of new lands. We are, in England, too prosperous, too peaceful, too settled; we are not at grips with problems that count; if one crop fails, another succeeds; we have not staked our all on a crop of apples nor does American Blight or Codlin moth really matter, bad though they are; nor if it does matter, can we apparently stir up any interest in getting anything done; so we in England take things easily, we have practically no legislation, every man may disseminate disease from his neglected garden and, in a great deal, we must look to the Colonies to give us a lead.

With this invitation we expect all who have interests common with our members here to join, and we look for support from all who are solving the big problems of applied biology and who can learn from the experience of others and with their own experience help others who have similar problems to work out.

Migration of Ladybirds.

The following note by Mr A. D. Walker, was read by Professor Newstead at the last meeting of the Association:

The following fact in the bionomics of the common "Ladybird" (*Coccinella*) may interest you.

Mrs Walker's bedroom has three windows, two facing south and one east. Since 8 a.m. to-day something like 100 Ladybirds have been taken on the east window *only*—none on the two south windows, except a few on the one next to the east end. The same thing happens every year—always the east window! It is not because of east winds for the winds here lately have been predominantly southerly and this morning there was a "moderate gale" from W.S.W.

There are roses trained both on south and east sides, so their presence will not account for Coccinella's preference for the latter.

The only way I can see to account for it is that there must be a spring migration from the continent. Our house, standing on the top of a fairly steep slope to the east, on which side there is a valley, would be a conspicuous obstacle to the insects flying across it. But it is curious that they should be so abundant this year when there has

been so little east wind and that with so much southerly wind, they should not strike the long south side of the house. It looks as if they could only cross the channel at the Strait of Dover which lies east from us; also that they can fly "on a wind"—*i.e.* with a side wind.

Another migration note. Last November countless flocks of Wood Pigeons flew over the great Kings Wood here. Some, perhaps all, stopped to have a feed of acorns but nearly all flew on to the west to become such a plague in Wilts and Dorset, that they have had armies of men with guns to shoot them. Here I can say with confidence that I have not seen a dozen since Christmas, though constantly in Kings Wood!

Surely this is a *blind* migratory impulse like that of the Lemmings!

Westminster Hall Roof.

The fine timber roof of Westminster Hall has suffered great damage from the attack of the larger timber-boring beetle, *Xestobium tesselatum*.

A committee has been meeting to advise the Office of Works and an investigation into the beetle has been commenced by Mr J. W. Munro at the Imperial College of Science and Technology. We refer to this since the preservation of this roof is really a matter of national interest and because members of the Association may be able to materially assist if they can help Mr Munro to get infested timber. Naturally the timber in the roof cannot be cut to provide material for experiment and a large supply of beetles and timber is an essential for testing the many possible lines of treatment that have been proposed. It is curious how little is known of this beetle and one very essential fact is not apparently definitely known, whether the beetles emerge from the wood or whether they can continue reproducing inside the large timbers, only emerging if they wish to. It might be easy to prevent the re-entry of beetles if they had to emerge, but, as it is, no treatment to the outside of the wood only can be adopted for fear it might keep them inside and intensify the damage. It is probable that a satisfactory treatment will be found.

Notes.

We shall be glad to receive notes on matters of current interest and on investigations in progress for publication in these pages; it is an accident that the notes in this issue are mainly of entomological interest; all members of the editorial Committee will be glad of short contributions which may be sent to them or to the General Editor direct. For the notes in this issue the General Editor alone is responsible except where stated.

H. M. L.